

Catch a Hop on a WWII Bomber—Flak Free

# AIR & SPACE

Smithsonian

## Dream Team

## The Idea Factory at NASA's Flight Research Center



MAR 1998 • \$3.95 U.S./\$4.50 Canada



The only convertible that matters.





The next Vette.



# AIR & SPACE

Smithsonian

## CONTENTS



18

### 18 Seven Days at Dryden

by Peter Garrison Photographs by Chad Slattery

*At this NASA research center, ideas fly as far and wide as the experimental aircraft.*

### 28 Gone but Not Remembered Text and illustrations by Bruce McCall

*Familiar with every arcane airplane in the book? Have we got a collection for you.*

### 34 Bigfoot by John Sotham

*Sometimes the hardest design challenge isn't getting aircraft into the air but getting them back on the ground.*

### 45 Bomberville by Lance Thompson

Photographs by Michael Melford

*In which a tiny air force has an impact far greater than its numbers suggest.*



34

### 52 Rockets for the Rest of Us by Charles Petit Photographs by Phil Schofield

*A group of young companies is reaching for an old dream: cheap—and profitable—access to space.*

### 60 Igor Sikorsky's Little Bird by John Fleischman Photographs by Brad Trent

*A modern replica of a 1915 Russian fighter faced its own series of battles.*

### 66 Commentary: Fortress Mentality by Senator John McCain

*Airlines' survival strategies are costing consumers too much money. It's time Congress intervenes.*

### 68 Star in a Bottle by Billy Goodman

*It's an astrophysical version of bringing the mountain to Muhammad, and it may revolutionize the field.*



68

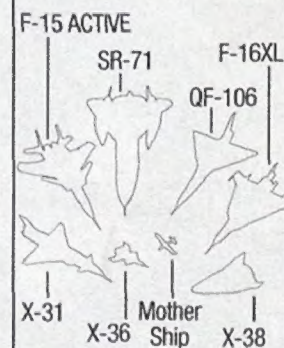


**Cover:**  
Chad Slattery  
photographed this  
group of research  
craft from a  
bucket lift near  
Dryden's main  
hangar.

#### Departments

- 4 Viewport
- 5 Letters
- 8 Soundings
- 14 In the Museum
- 16 Above & Beyond
- 78 Sightings

- 82 Reviews & Previews
- 84 Credits
- 85 Calendar
- 86 On the Web Site
- 86 Forecast
- 87 Collections



**AIR & SPACE/Smithsonian** (ISSN 0886-2257) is published bimonthly by the Smithsonian Institution, 900 Jefferson Drive, Washington, DC 20560. ©Smithsonian Institution, 1998. All rights reserved. Reproduction in whole or in part without permission is prohibited. Editorial offices: 901 D St. SW, 10th Floor, Washington, DC 20024. Advertising and circulation offices: 420 Lexington Ave., New York, NY 10170.

**SUBSCRIPTION PRICES:** U.S. and possessions: \$20 a year payable in U.S. funds. Canada and all other countries: add \$6.00 (U.S. funds) per year. Eighty-five percent of dues is designated for magazine subscription. Current issue price: \$3.95 (U.S. funds). Back issue price: \$5.00 (U.S. funds). Periodical postage paid at Washington, D.C., and additional mailing offices. **MAILING LISTS:** We sometimes make our

subscriber list available to companies that sell goods and services by mail that we believe would interest our readers. If you do not want to receive such mailings, send your current mailing label or exact copy to: **AIR & SPACE/Smithsonian**, Mail Preference Service, PO Box 420113, Palm Coast, FL 32142-0113. **ADDRESS CHANGES AND SUBSCRIPTION ORDERS:** mail to **AIR & SPACE/Smithsonian**,

PO Box 420113, Palm Coast, FL 32142-0113; call 1-800-766-2149 (outside the U.S. call 1-904-445-4662); visit Web site <http://www.smithsonianmag.si.edu>; or go to the Smithsonian Online area of America Online (keyword: Smithsonian Magazine). Postmaster: Send change of address to **AIR & SPACE/Smithsonian**, PO Box 420111, Palm Coast, FL 32142-0111.

# We

know you'll love our coffee.  
know you'll love the free coffeemaker.  
just don't know what color your kitchen is.

It all began in 1853, in the tiny port of Gävle, Sweden. Here, Victor Th. Engwall established an import company dedicated to bringing the finest coffee in the world to Europe's most passionate coffee lovers.

## A TIME-HONORED COMMITMENT TO EXCELLENCE.



Over the years, Engwall's descendants became obsessed with creating the perfect cup of coffee. Using the world's most prized Arabica beans, generations of Engwalls diligently roasted and blended, tasted and tested. When King Gustav V visited Gävle and sampled Gevalia®, he was so delighted he appointed Gevalia® Kaffe purveyor to the Swedish Royal Court. An honor we still hold to this day.

## SHARE IN A EUROPEAN OBSESSION.

Now you can have the rich, distinctive taste of Gevalia conveniently delivered from our European roastery to your home. Gevalia comes vacuum-sealed in half-pound foil pouches to

preserve freshness, and is available in Traditional Roast® Regular or Naturally Decaffeinated, whole bean or ground.

## A TRULY REMARKABLE WELCOME GIFT.

To make our offer even more enticing, we're delighted to include a beautiful, 10-cup Automatic Drip Coffeemaker with your Trial Shipment. This European-style coffeemaker features an exclusive aroma lock system and High-Extraction filter cone that ensures you'll capture the full richness of your Gevalia Kaffe. This elegant, high-quality coffeemaker (retail value \$44.95) available in hunter green, soft white or jet black, is our gift with no further obligation.

So call us at  
**1-800-GEVALIA**  
(1-800-438-2542), or send  
in the coupon below.



*Let us welcome you  
to Gevalia® Kaffe with an  
elegant, FREE coffeemaker  
in your choice of  
hunter green, soft white or jet black.*

## FOR FASTER SERVICE CALL 1-800-GEVALIA

☐ **Yes**, I'm searching for a great cup of coffee and would like to try one pound of Gevalia® Kaffe for \$10, including shipping and handling, and receive with it the Automatic Drip Coffeemaker (retail value \$44.95) in hunter green, soft white or jet black, as a free gift.

Please send Gevalia Kaffe—two 1/2 lb. packages of the type(s) indicated below—with the understanding that I will continue to receive shipments of Gevalia® approximately every six weeks, plus a special holiday shipment. I understand that I may cancel this arrangement at any time after receiving my introductory shipment without obligation to accept further shipments. The Automatic Drip Coffeemaker is mine to keep regardless of my decision.

Check Coffeemaker: ☐ Green (EG) ☐ White (WH) ☐ Black (BL)

Check One: ☐ Whole Bean (1) ☐ Ground (2)

Check One: ☐ A. 1 lb. Traditional Roast® Regular ☐ B. 1 lb. Traditional Roast® Decaf  
☐ C. 1/2 lb. Traditional Roast® Regular and 1/2 lb. Traditional Roast® Decaf

Charge my: ☐ Visa ☐ MasterCard ☐ American Express ☐ Discover Card

Card number/exp

Signature

CODE: 909044

☐ Enclosed is my check payable to Gevalia Kaffe for \$10.

Name

Address

City/State/Zip

Phone ( )

(Area Code)

COMPLETE AND MAIL THIS COUPON TO:

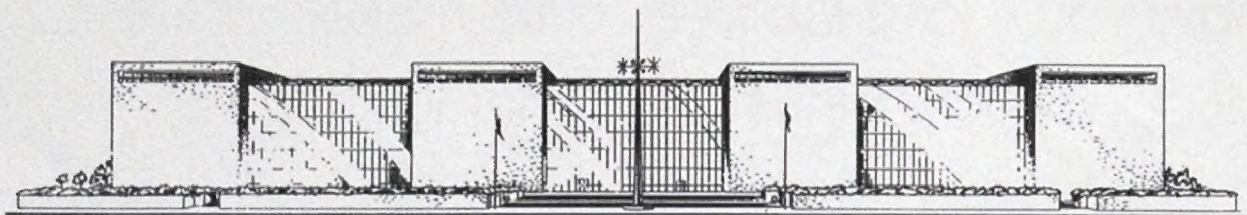
GEVALIA KAFFE, P.O. BOX 11424, DES MOINES, IOWA 50336-1424

# GEVALIA® KAFFE

FINE COFFEES OF EUROPE

HERE'S WHAT YOU CAN LOOK FORWARD TO. 1. You must be pleased with Gevalia Kaffe or you may cancel and keep the free coffeemaker. 2. If pleased, do nothing and a shipment of four 1/2-lb. packages (2 lbs. total) of the type(s) you selected will be shipped to you approximately one month later. You will then receive the same shipment once every 6 weeks. Once eligible, each year you will also receive a special holiday shipment of Gevalia Kaffe. You will be notified in advance with details of this special shipment and its seasonal price; you may cancel any shipment you do not wish to receive. 3. You will be billed only \$5.55 per 1/2-lb. package of Gevalia Kaffe Regular and \$6.25 per package for Decaffeinated, plus an added shipping and handling charge. Coffee

prices are subject to change. 4. You may pay upon receipt of each shipment or, for those using credit cards, subsequent shipments will be conveniently billed to your card. 5. You may change the frequency, quantities or types of Gevalia Kaffe you receive, or cancel the arrangement at any time. Shipments may be returned at our expense. 6. Offer is subject to change and is open to residents of the U.S., the U.S. Virgin Islands and Puerto Rico and is only valid for NEW MEMBERS of the Gevalia Kaffe program. Gevalia Kaffe reserves the right to substitute a coffeemaker of equal or greater value when limited supplies are exceeded. Limit one membership per household. Coffeemaker offer expires 1/31/99. ©1998 Gevalia Kaffe.



# A 70-Year Question

**C**harles Lindbergh carried the flag for the United States when he bet his fortune and his life that he could fly solo from New York to Paris. On May 21, 1927, he single-handedly beat the odds. To fly nonstop from the United States to the continent of Europe was the greatest achievement of that time, and people on both sides of the ocean showered him with adoration.

The flight entailed a takeoff at high gross weight, an incredibly long time in the air (more than 33 hours on little or no sleep), poor visibility, an engine of unknown reliability, monotony, large regional differences in Earth's magnetic field (called "magnetic variation") that affected his compass over the great distances he covered, and more. All these factors were characterized by one four-letter word—risk! It was a high-risk flight, and when he completed it, Charles Lindbergh captured the hearts of all.

A few people saw him leave Roosevelt Field on Long Island, a very few saw his airplane along his route of flight, and thousands saw him arrive at Le Bourget airfield, near Paris. Last year, yet another witness to that flight of 70 years ago came forward for the first time.

His name is Ginger Reed, and he lives in South Africa. He wrote me a letter saying he thought he had seen Lindbergh's airplane as it flew over a field in Cornwall, England, an hour before sunset on May 21, 1927. He said that at the time he saw it, he was a 12-year-old boy working alone in a rock-strewn pasture near his small village of St. Breward.

As Reed looked toward the sound of a lone airplane engine, he was surprised to see the airplane come out of the west, flying low over the hedgerows. It passed overhead and continued to fly steadily eastward to...he was not sure where.

Reed had never heard of any of the 700-odd people living near St. Breward claiming to have seen the airplane that evening—for all he knew he was the only one. Now, 70 years later, he wondered: Could this really have been Lindbergh?

Reed went on to tell me that he left school two years later to work full time in the fields, went on to military service in World War II, and then took up a career in manufacturing. He eventually emigrated to South Africa, but throughout, he had never forgotten that day in 1927 and he had never resolved the question of whether that airplane had been Lindbergh's.

To help him settle the matter, National Air and Space Museum curator Robert van der Linden searched through Lindbergh's papers, charts, and books in the Museum's archives and found that Lindbergh had indeed flown over that spot in Cornwall during the 31st hour of his flight. Lindbergh's records show that he had dropped down to fly at 500 feet above mean sea level to cross the narrow spit of land that was Cornwall. In his book *The Spirit of St. Louis* he takes note of the people below: "People raise their heads as I fly over them," he wrote. "Do they know they are looking at the *Spirit of St. Louis*—a plane which has travelled from the United States to England in thirty hours?"

I wrote back to Reed relating all this, and he responded with a letter expressing thanks and relief that we had solved one of his life's mysteries. Now, at age 82, he would write the correspondent of the magazine at St. Breward, where he said nothing had ever happened, to let them know that the village was positively connected to the historic flight of Charles Lindbergh in 1927. At last the villagers had something to brag about.

Charles Lindbergh's original Ryan NYP airplane, bearing the registration NX-211, today soars high above the heads of millions of visitors to the National Air and Space Museum. Except for its cabin door, now deliberately left slightly ajar, the *Spirit of St. Louis* is as it was on that momentous flight when it passed over the head of an English boy and continued on its way to Paris and into aviation history.

—Don Engen is the director of the National Air and Space Museum.

## AIR&SPACE

Smithsonian

Secretary of the Smithsonian Institution  
I. Michael Heyman

Editor  
George C. Larson

Executive Editor  
Linda Musser Shiner

Senior Editor  
Patricia Trenner

Senior Associate Editor  
Perry Turner

Associate Editors  
Karen Jensen  
John Sotham  
Diane Tedeschi

Photography/Illustration  
Caroline Sheen

Design Direction  
Phil Jordan  
Gretchen L. Maxwell

Cover Design  
Lasko Design

Publisher  
Ronald C. Walker

Administration  
Carey O. Randall, Associate Publisher

Advertising  
Louis C. Kolenda, DEO LLC

Circulation  
Liberta Abbondante, Director  
Caroline Topak, Marketing Director  
Elizabeth Hopkins, Planning Director  
Andrea Sole, Fulfillment Director

Production  
Sarah D. Kingsley, Manager  
Sue Nixon, Editorial Production

Business  
Shelia Perry Brannum, Manager

Founder  
Walter J. Boyne

Publisher Emeritus  
Joseph J. Bonsignore

Telephone/Fax numbers  
Editorial: (202) 287-3733;  
fax: (202) 287-3163  
Advertising: (415) 454-9782;  
fax: (415) 454-9785

Secretary of the Smithsonian Institution  
I. Michael Heyman

Director, National Air and Space Museum  
Vice Admiral Donald D. Engen,  
U.S. Navy (ret.)

Board of Regents, Smithsonian Institution

*Ex Officio*

Chief Justice of the United States  
William H. Rehnquist, Chancellor  
Vice President of the United States  
Albert Gore Jr.

*Appointed by the President  
of the Senate*

Honorable Thad Cochran  
Honorable Bill Frist  
Honorable Daniel P. Moynihan

*Appointed by the Speaker of the House*

Honorable Sam Johnson  
Honorable Bob Livingston  
Honorable Esteban E. Torres

*Appointed by Joint Resolution of Congress*

Honorable Howard H. Baker Jr.  
Honorable Barber B. Conable Jr.  
Mr. Louis V. Gerstner Jr.  
Dr. Hanna H. Gray  
Ms. Anne d'Harnoncourt  
Dr. Manuel L. Ibáñez  
Dr. Homer A. Neal  
Mr. Frank A. Shrontz  
Mr. Wesley S. Williams Jr.

*Contributing Editors,  
Air & Space/Smithsonian*

Michael Beschloss	Frank Kuznik
Roger Bilstein	W. David Lewis
William E. Burrows	Stephen Maran
Eric Chaisson	Laurence Marschall
Tom Crouch	Ted Maxwell
David DeVorkin	Ron Miller
Ron Dick	James Oberg
Freeman Dyson	Edwards Park
Daniel Ford	Dominick Pisano
Greg Freiherr	Robert E. Pollack
Owen Gingerich	Fred Reed
Donald Goldsmith	Tony Reichhardt
Stephen Jay Gould	George Robinson
George Greenstein	Theodore Robinson
William Gregory	Chad Slattery
R. Cargill Hall	Marcia Smith
Richard Hallion	Robert W. Smith
Jim Hansen	Jill Tarter
Gregg Herken	Steven L. Thompson
Nick Komons	Albert Van Helden
Nick Kotz	G.L. Verschuur
Saunders B. Kramer	Stephan Wilkinson

## Free the GPS Three

By not releasing the Global Positioning System's three-meter-accuracy signal to the public at large ("GPS, Inc.," Commentary, Dec. 1997/Jan. 1998), the military is costing taxpayers money. One example can be found in the pending expansion of the Seattle-Tacoma International Airport. The expansion was deemed necessary because the present main runways are spaced only 1,500 feet apart, and the Federal Aviation Administration requires that for side-by-side Instrument Landing System landings, runways must be 2,500 feet apart. Therefore, during inclement weather, when ILS is employed, only one main runway can be used. The cost of the planned third main runway, including the expense of noise mitigation, is projected to be over \$2 billion.

If GPS's three-meter accuracy could be used, simultaneous landings could be made safely on the two present runways. The construction of a third runway could be avoided. Multiply these savings by other increasingly congested airports across the nation, and continued Air Force control over the GPS system begins

to lose some of its luster.

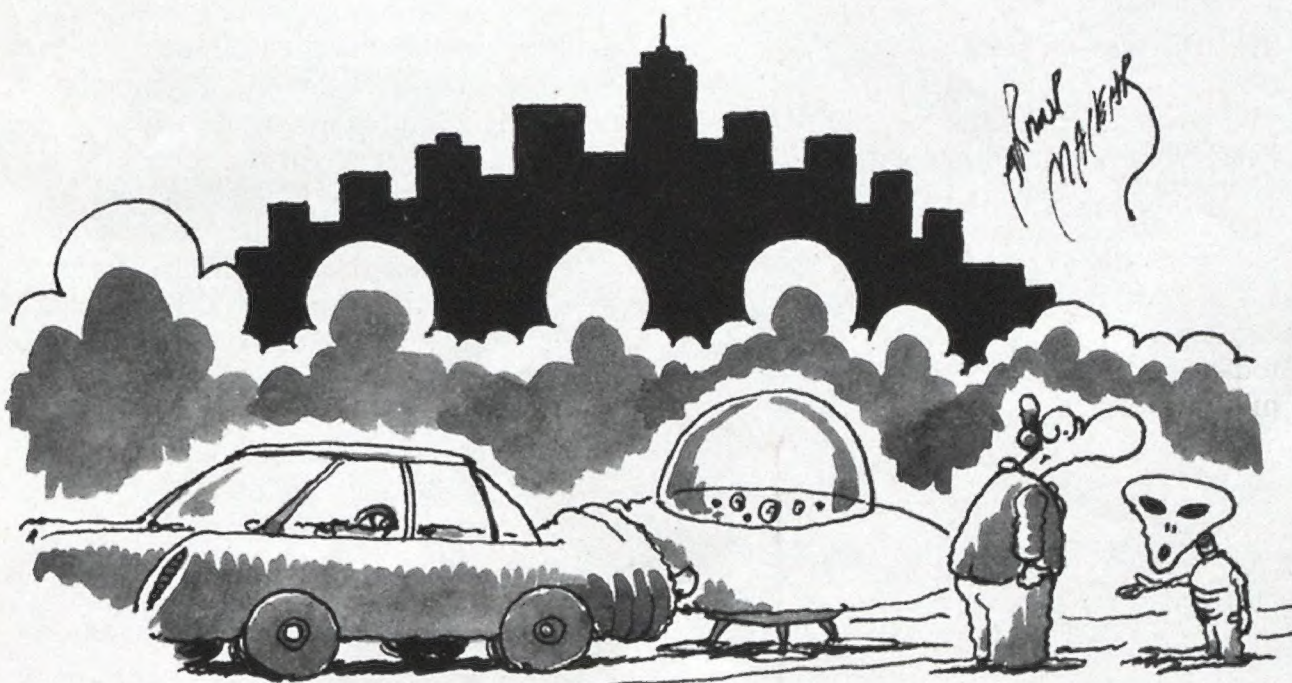
Perhaps an alternative to privatization would be the formation of a quasi-private public corporation such as the U.S. Postal Service or Conrail. This would allow the Air Force to take the GPS off budget, enable the U.S. taxpayers to recoup their investment, and still allow the military to maintain control in the event of a national security crisis.

—Jack S. Block Jr.  
Burien, Washington

## Treasure Hunt

The publication of "Watson's Whizzers" (Oct./Nov. 1997) coincided with a related project our aircraft maintenance school is participating in. Along with Salvage I, an aircraft salvaging company, we have been using underground radar to search Freeman Field in Indiana for the remains of German and Axis aircraft, such as those mentioned in your article.

Last August we recovered spare engine cylinders, propeller blades, Me 109 gear doors, fuselage parts, and even a Jumo jet engine. However, we are convinced that whole aircraft were also buried there. We



"Take me to your lawyer."

would appreciate hearing from those who served at Freeman Field in the spring of 1947, when it was decommissioned, as well as those who know of other sites where old aircraft may be buried.

—Gerald Yagen, President  
Tidewater Tech  
4455 South Blvd., Suite 500  
Virginia Beach, VA 23452  
(757) 490-3989

### The Triumph of Secret Squirrel

The timeline in "Tankers" (Oct./Nov. 1997) says that in 1996, B-52s participating in Operation Desert Strike flew the longest combat mission in history—36 hours. That mission actually lasted 33.9 hours. In the 1991 mission commonly referred to as Secret Squirrel, seven B-52Gs logged 35.4 hours of combat time, and that constitutes the longest combat mission in history.

—Major Warren G. Ward  
Bossier City, Louisiana

### China's Achilles' Heel

I was surprised that in "Secret Mission to Tibet" (Dec. 1997/Jan. 1998), William Leary did not mention fighter coverage. I assume that when the Chinese occupy, they bring air power with them. The Chinese must have known of our presence in Tibet; didn't they have ground anti-aircraft artillery or fighter intercepts?

—Chris Pierce  
Tucson, Arizona

*William Leary responds: During the late 1950s the Chinese air force sent only bombers and light reconnaissance aircraft into Tibet. It had few trained night fighter pilots, limited radar, and, in the remote regions where the drops were made, no anti-aircraft artillery.*

### Beneath Our Notice

The photographs of a Beechcraft Bonanza flying through the arches of the Eiffel Tower (Sightings, Dec. 1997/Jan. 1998) show the airplane passing over a couple of tour buses, at least two campers, and numerous people milling about under the arches. The pilot (an ex-Marine, yet) deserves to be disciplined for jeopardizing lives in his juvenile "bid for glory," as you called it. I am appalled that you would condone

such unprofessional behavior by giving it notice in your esteemed publication.

—Captain Milt Jines  
United Airlines (ret.)  
San Mateo, California

### Forgotten Pilots

In your item on General Chuck Yeager's flight commemorating the 50th anniversary of his breaking the sound barrier (Soundings, Dec. 1997/Jan. 1998), you reported that Bob Hoover flew chase in an F-16. Actually, an active-duty Air Force pilot was in the F-16's front seat, and another was in the back seat of the F-15 Yeager was flying.

I also noted that three pages earlier, the article "Sighted Sub, Sank Same" did not mention Zack Mosley, who drew the Smilin' Jack panel used to illustrate the piece. Zack used the Smilin' Jack comic strip to promote the Civil Air Patrol. During World War II, he flew many hours with the CAP looking for German submarines off of Florida; later, he served as Florida CAP wing commander. I am a little prejudiced in this matter because Zack was my father.

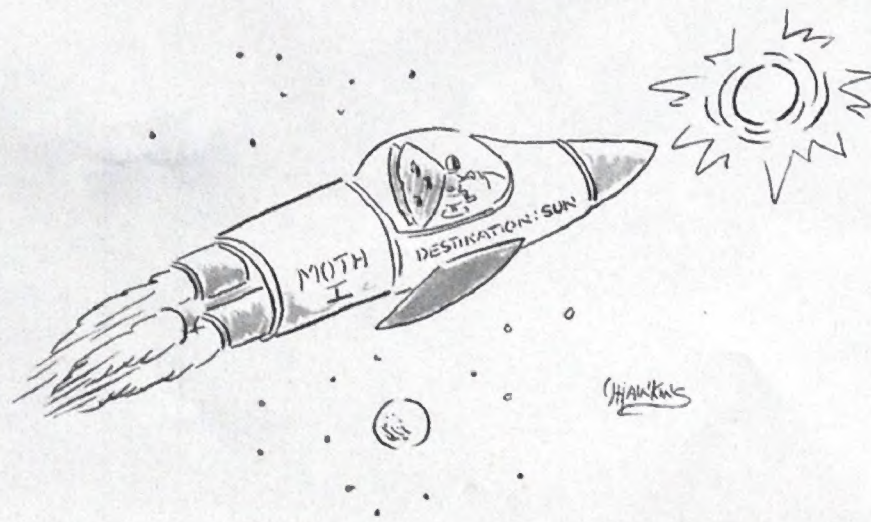
—Lt. Col. Bob Mosley  
U.S. Air Force (ret.)  
Merritt Island, Florida

Much attention is focused on the Civil Air Patrol's World War II beginnings ("Sighted Sub, Sank Same"), but everyone seems to forget that CAP is alive and well today. The organization still carries out vital search-and-rescue missions and also serves as a leader in aerospace education. Each year our cadet programs contribute eight to 10 percent of the U.S. Air Force Academy class.

—Max Rosenthal  
CAP Cadet Technical Sergeant  
Fairfield, Connecticut

### 20,000-Wave Checkup

The article "20,000-Mile Tuneup" (Oct./Nov. 1997) reminded me of my



experiences as a mechanic at Pan American during the early 1940s, when we provided transoceanic service with the Boeing 314 Clipper flying boats. Imagine the maintenance procedures described in your article complicated by a boat hull, four 18-cylinder Wright Cyclone engines on a high wing, rubber de-icer boots, full feathering propellers, and constant saltwater corrosion of every metal part. In addition, after each hangar servicing we would clean the hull and coat it by hand with lanolin. And all fuel was filtered through chamois skin to prevent water contamination.

—Lester P. Kappel  
Lido Beach, New York

### Improving Our Coverage

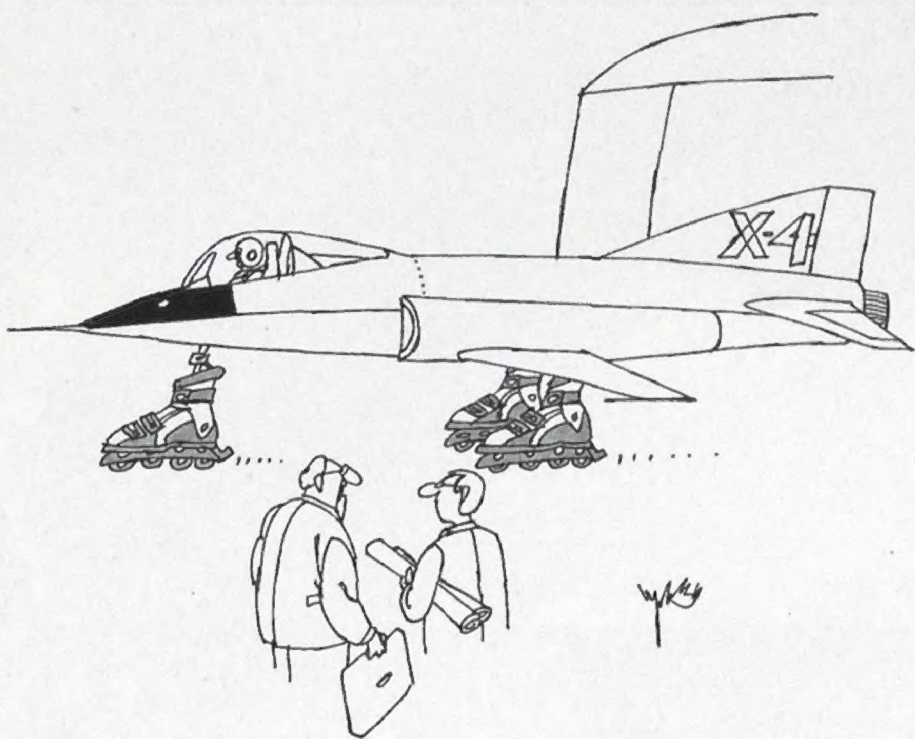
"Spacesuit Saga: A Story in Many Parts" (Aug./Sept. 1997) gave a great deal of well-deserved attention to ILC Dover, the manufacturer of the spacesuit's fabric parts. However, the spacesuit primary contractor is Hamilton Standard. We are responsible for the overall design and integration of all the hardware made by approximately 80 subcontractors (including ILC Dover). Your article noted that we supply the primary life support system, but we also supply such hardware as the hard upper torso and the secondary oxygen pack. In addition, our Houston-based subsidiary monitors suit performance during testing and flight and modifies suit design to meet new requirements.

—Harry Garfinkel, President  
Hamilton Standard Space Systems Intl.  
Windsor Locks, Connecticut

### Paying Homage

Last November, engineer G. Harry Stine, one of the founding fathers of model rocketry, passed away. Stine was a founding member of the National Association of Rocketry (he was member no. 2). He authored numerous works, including articles for *Air & Space/Smithsonian* ("Pushing the Button," Feb./Mar. 1988; "The Rises and Falls of Henri-Marie Coanda," Aug./Sept. 1989), and his *Handbook of Model Rocketry* has been the bible of the hobby. Stine also developed the safety guidelines and modeling techniques still used by rocketeers today.

I was one of the young rocketeers fortunate enough to launch rockets alongside NAR member no. 2. Back in 1978, Stine was the advisor emeritus of our Phoenix rocket club, and



*"I told you to take the young designers off the project."*

he spent many a Saturday morning doling out guidance and expertise in an efficient, almost military manner, as if he were a NASA engineer prepping a Saturn V launch.

But when he'd press that ignition button the formal facade disappeared and his twinkling eyes would follow his rocket's skyward arc. At that moment, he was just another kid out launching rockets on a Saturday morning.

—Mark Jonathan Davis  
Los Angeles, California

*Editors' note: A review of Stine's last book, Living in Space, appears on p. 83.*

To honor the memory of aerobatic pilot Leo Loudenslager (Soundings, Oct./Nov. 1997), Sussex Airport owner and manager Paul Styger would like to establish a memorial at the airport, which is where Leo's Laser 200 was born. One possibility being considered is a one-third-scale bronze mockup of that airplane.

Contributions are welcome. They should be made payable to The Leo Loudenslager Memorial Fund and sent to:

Sussex Airport, Inc.  
PO Box 311  
Sussex, NJ 07461

—Michael Stendor  
Former Bud Light 200 Crew Chief  
Franklin, New Jersey

#### Correction

Dec. 1997/Jan. 1998 "Monster Engines": The Merlin V12 1650 had 48 valves, not 24.

*Write to us at: Letters, Air & Space/Smithsonian, 901 D St. SW, 10th Floor, Washington, DC 20024. Please type or print clearly. You must include your full address and daytime phone number. Letters will be edited for publication.*

*Air & Space is not responsible for the return of unsolicited photographs or other materials. We regret that we cannot answer every letter personally.*

**e-mail** You must include your full name, mailing address, and daytime phone number. America Online: airspacedt, Compuserve: airandspace, Internet: editors@airspacemag.com.

Air&Space February/March 1998

## DESIGNED FOR MILITARY PILOTS

NEWEST MODEL.  
ALL NEW  
FEATURES



**Now You  
Can Own It  
Even If You  
Don't Fly A  
Fighter Jet!**



**PILOT  
COMMANDER**

**PRECISION SEIKO YM55 Quartz Movement**

7 Hands, 4 Dials, 3 Pushbuttons, Solid 316L Stainless Steel Case & Band, Sapphire Lens, Tritium Hands, Unidirectional Flyback Sweep, Speed Tachymetre, 1/10th Second, Split Second, Partial and Lap Times, 6 Hour Timer, W/R to 330 ft, Revolving E6B Flight Computer Bezel, Date Window, Ltd. 5 Year Warranty, Same Day Shipping. 30 Day Money Back Guarantee

\$400 Value **ONLY \$179** +\$6 S&H

**CREDIT CARD ORDERS  
CALL: 1-800-544-4365**

ASK FOR OPERATOR 531

**CHASE-DURER Ltd.**

270 No. Canon Dr. • Dept 1402-531 • Beverly Hills, CA 90210  
Phone: 310.550.7280 / Fax: 310.550.0830 /  
www.WatchShop.com

## Toy Story

**W**hen the Mars Pathfinder bounced to a landing on the Red Planet last summer, it was another big win for NASA. But the mission may ultimately prove to be of less value than its public relations spinoffs, in particular the Mattel Hot Wheels version of the Mars Rover, which was one of the toy sensations of the year.

"I can't tell you how much of a shock it's been," says Merle McKenzie, manager of the Jet Propulsion Laboratory's Commercial Technology Program. "We thought one of our other technology transfer programs would be the big payoff. And they have paid off—but nothing like this."

Profit and sales figures in the toy industry are traditionally a deep secret, and no one at Mattel or JPL is divulging any numbers. But the Hot Wheels Rover flew off store shelves, particularly after TV commentators began using it to explain the mission. Four months after the July 4 landing, with the real Rover somnolent, Mattel had doubled production capacity and was still struggling to keep up with demand.

"We have 747s flying in every day from [the manufacturing facility in] China, shipping a phenomenal number of these things," says John Handy, Mattel senior vice president of product design. "We'll be making them well into 1998 and beyond. This is on the order of Tickle Me Elmo or Cabbage Patch dolls."

Thanks to a precedent-setting licensing agreement, JPL gets an undisclosed cut of every \$5 Rover sold. But it's the publicity value that really excites NASA managers. "We're always searching for ways to communicate what we're doing and why people should care," McKenzie says. "What this has done is taken our minuscule outreach budget and leveraged it like crazy."

The Mattel agreement is part of a larger JPL effort called the Technology Affiliates Program, which began working with private industry 10 years ago, usually on specific technical problems and software licenses. The program has generated \$16 million worth of business



ERIC LONG

for JPL from over 120 companies, many of them repeat customers. But there's not much media allure in remote sensors and GPS software.

In 1995, JPL Business Alliance manager Joan Horvath tried to open a new market by holding the first licensing workshop on space toys and games. The idea was to tap the many small businesses in southern California doing creative work for the entertainment industry. "What we ended up drawing was Mattel," Horvath says.

"To be honest, it was less the scientific significance of the [Pathfinder] mission that attracted us than the milestone event of the first vehicle to drive on another planet," Handy explains. But Hot Wheels designers and engineers found they had a lot in common with their JPL counterparts. "Our biggest problem in the toy business is how to get the greatest performance and play value out of

something that doesn't cost a lot," says Handy. "Those guys are in the same boat, trying to go to Mars on a budget."

Still, hammering out the licensing agreement took a full year. "The cultural divide was not small," Horvath recalls. "At our very first meeting, John said, 'If we're going to make this toy, could you put pinstripes or a Mattel logo on the real one?' That's a perfectly reasonable thing to ask if you're going to do a movie or something. But it was such a bizarre question here, no one knew what to say. I wanted to crawl under the table."

The keys to the final agreement were accuracy and exclusivity. JPL was guaranteed a toy that would faithfully copy the original; in return, Mattel was given exclusive rights to Pathfinder/Rover

reproductions, the first time NASA ever granted such rights. "Until we could offer that kind of protection," Horvath says, "there was no real incentive for a company to spend money developing a high-quality accurate product."

Certainly there is now. Eager entrepreneurs had to be turned away from the second JPL toy workshop, held in 1996, because there was no more room. The third workshop was held in a larger auditorium last October, where some 90 attendees were given previews of upcoming missions, a tour of the facilities, and an invitation to come back with toy proposals—good ones, please.

"We want our licensed products to be very accurate and educationally worthwhile," says Horvath. "We try to hold everyone to what's called Joan's No Green Martians Rule: If it's too fanciful, they don't need us."

—Frank Kuznik

## NASA's 757 Bust

NASA has replaced its venerable Boeing 737 with a 757 as the agency's primary flight research aircraft. The 757 can carry much more test equipment, it generates more than twice the electrical power, and instead of an analog data handling system, it came equipped with a modern digital data bus. It also came equipped with more than 10 pounds of high-grade cocaine.

The 757 was the second of its kind to be built; it first flew in 1982. Following purchase by Eastern Air Lines, it saw years of service on Latin American routes, where not all the traffic is of the ticketed passenger variety. When Eastern folded, this airplane, like much of the airline's fleet, ended up parked in the Nevada desert. There it remained, like a Cracker Jack box with a surprise inside, until 1994, when NASA purchased it from the Eastern estate for \$24 million.

Before taking possession of the aircraft, NASA had it ferried to Lockheed Aeromod Center in Greenville, South Carolina, for restoration and conversion work. Around 11 one evening a night shift crew was removing the galley and lavatories from the center of the aircraft when the workers spotted a burlap bag behind a wall panel. At first they thought it contained desiccant, used to keep aircraft interiors dry while in storage. But when a mechanic opened the bag, he found five packages, tightly wrapped in plastic. He sliced one open, stuck his finger inside, and tasted the white powder. Instantly the man's tongue went numb.

All workers were pulled off the aircraft,

### UPDATE

#### Back in the Space Race

The Ariane 5 booster made its first launch last October 30 when it vaulted into geostationary transfer orbit a dummy communications satellite and a science test package—both of which unfortunately ended up some 2,000 miles below the planned altitude. In an earlier launch attempt, conducted in June 1996, a software error had caused the mega-booster to tumble out of control and self-destruct in Europe's worst space accident ("Ariane 5 Fails," Soundings, Aug./Sept. 1996). The next Ariane 5 test launch is scheduled for the second quarter of this year.

### UPDATE

#### Branson Balloon Jumps the Gun

One of the five balloon teams competing to be the first to circle the globe ("Thin Air, High Hopes," Apr./May 1997) lost its grip on its transport in Marrakesh, Morocco, last December. Richard Branson looked on in horror as his partially inflated Virgin Global Challenger ripped free of its moorings when a taxiing jet passed too close. The balloon soared off without its capsule or crew. After reaching 60,000 feet, it landed that night in the Algerian desert, where local troops guarded it until it could be retrieved. Prior to the uneventful landing, Branson had asked the Moroccan and Algerian air forces to put "about 100 neat bullet holes through the upper part of the balloon" in hopes that it could be brought down in salvageable shape. His requests were denied.



AP PHOTO/CLIVE HOWES/POOL



AP PHOTO/CEAS BRETON

the doors were sealed, and the local sheriff's office was notified. Soon law enforcement officers and drug-sniffing dogs descended on the hapless 757. Analysis placed a street value of \$125,000 on the shipment.

No arrests were made in the case. Investigators concluded that a smuggling operation was interrupted when the aircraft was diverted to desert storage more than three years earlier. Frank Rose, special agent with the Drug Enforcement Administration's aviation division, says that such illicit use of airliners is relatively common. It's often easier and safer to "steal space on an airplane," he says, than to use your own aircraft. "That way offers a degree of security. You're not carrying the drugs in your own briefcase, so if necessary you can just walk away."

By the time the 757 reached NASA, it was certifiably drug-free. With its outlaw days behind it, the reformed airliner was put to work as the agency's biggest airborne laboratory, supporting development of such efforts as the advanced subsonic transport and the enhancement of airport traffic-handling capacity.

Meanwhile, NASA's older 737 is retiring after a career that was not as checkered as that of the 757, though no

less dramatic. The 30-year-old transport was the first 737 built. Its research achievements included electronic flight displays, airborne windshear sensors, and high-lift wing technologies. The 737 will go on display near its birthplace, at Seattle's Museum of Flight.

—Lester A. Reingold

#### Over the Volcano

The commercial airline industry has developed a healthy respect for volcanoes, with good reason. In December 1989, all four engines on a KLM 747 bound for Anchorage, Alaska, failed simultaneously after the aircraft flew near an ash cloud from the erupting Mount Redoubt in the Aleutians. The frantic pilots managed to restart the engines and land safely, but damage to the aircraft was extensive, running nearly \$80 million. Damage to the passengers' nerves was inestimable.

A similar encounter involving a 747 occurred near Galunggung, on the island of Java, in 1982, and dozens of milder versions have been reported. Several hundred flights each day pass near volcanically active regions, putting high-efficiency jet engines at extreme risk of flameout and damage due to ash particles. What's needed is a global system, preferably satellite-based, to help aircraft



**Every great journey begins with a single step.  
We even lit it for you.**

It's a step up into the all-new Navigator from Lincoln, but we made it easier by lighting the way. With available load-leveling air suspension that actually lowers the vehicle to help you get in and out. A command seating position for better visibility. And available Control-Trac 4WD for surefootedness. We're




**LINCOLN**

*\*Always wear your safety belt and secure children in the rear seat.*



also the first SUV to feature second-generation air bags\* that deploy with less force. For more information about this full-size luxury SUV, call toll-free 1-888-2ANYWHERE (1-888-226-9943), visit our web site at [www.lincolnvehicles.com](http://www.lincolnvehicles.com) or see an authorized Lincoln Navigator dealer.

**Navigator from Lincoln. What a luxury [  ] should be.**

steer clear of ash clouds. A good bit of the technology has been developed. But the system remains grounded, lacking funding and an orbital home.

Take the instrument that NASA has had in operation for several years. Called TOMS, for Total Ozone Mapping Spectrometer, it was originally developed in the late 1970s to monitor changes in the ozone layer. But TOMS has turned out to be quite useful in spotting volcanic hazards. It can differentiate between ash and ordinary clouds, even though the two look identical from space.

And the instrument can track another volcanic emission that is an expensive nuisance for aviation: sulfur dioxide.  $\text{SO}_2$ , which is invisible to the naked eye and ground-based radar, combines with water vapor in the atmosphere to form sulfuric acid, which is highly corrosive to aircraft windows and airframes.

Despite its appeal, TOMS has remained something of an orphan over the years, hitching rides aboard various satellites. Currently, the only satellite carrying a TOMS is NASA's Earth Probe, which is in low orbit and provides only limited coverage. TOMS provides real-time data on an experimental basis to the National Weather Service in Alaska, which in turn makes it available to air traffic controllers.

NASA researcher Arlin Krueger, who designed TOMS, says he hopes it

eventually can be carried by a network of geostationary satellites so coverage can be worldwide and real-time. One prime candidate would be a new generation of navigation satellites proposed by the Federal Aviation Administration. But that's unlikely for the moment, according to FAA officials, since the satellites are currently unfunded.

Meanwhile, NASA has been discussing the possibility of attaching TOMS to a new telecommunications satellite owned by USSB, a direct-broadcast concern, in exchange for underwriting part of the launch expense. That may or may not happen, according to Krueger, who adds, "Eruptions aren't a high-priority item at NASA."

That's unfortunate, because TOMS is relatively inexpensive technology. Each unit costs about \$6 million, considerably less than what the airline industry pays each year for repairing window and engine damage due to ash and  $\text{SO}_2$ . Even so, the airlines have not exactly jumped at the chance to fund the project. "They're used to getting data for free," says Krueger.

What may eventually launch TOMS worldwide is its original purpose: monitoring ozone. The National Oceanic and Atmospheric Administration is considering adding the instrument to its global weather satellites. TOMS' images of ozone in the upper atmosphere are so sharp that meteorologists can use the data to track jet stream activity with unprecedented precision.

—Phil Berardelli



DIGITAL IMAGE BY CORBIS © 1996 FROM NASA ORIGINAL

### Shoemaker's Ashes Will Rest on the Moon

A small amount of the ashes of Eugene Shoemaker, the planetary geologist who was killed in an auto accident in Australia last July, were launched aboard NASA's Lunar Prospector in January. The probe will orbit the moon for roughly a year; when its batteries fail it will crash on the lunar surface. "It brings a little closure, in a way, to our feelings," said Shoemaker's wife Carolyn. "We will always know when we look at the moon that Gene is there."

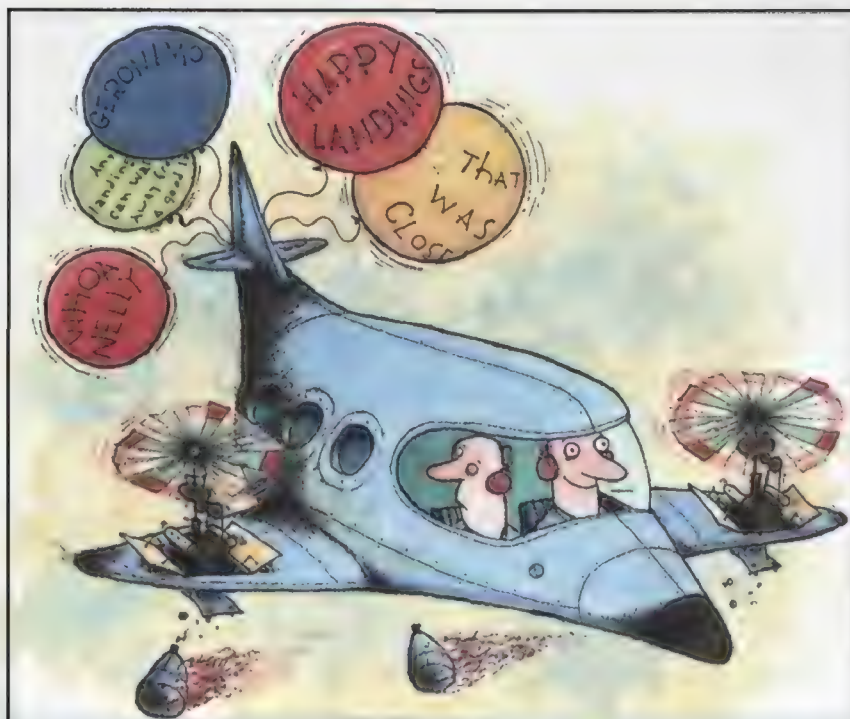
Shoemaker concluded that the giant crater in Arizona was caused by an asteroid impact, co-discovered the comet that smashed into Jupiter in 1994, and with Carolyn discovered some 800 asteroids and 20 comets. He was thwarted by illness in his desire to explore the lunar surface.

### For Sale: Gym, Airport Attached

Artifacts can reveal a lot about their originators, aviation's denizens included. The Wrights' letters underscore scientific minds in focused pursuit. Igor Sikorsky's Homburg was clearly an adornment of a gentleman with proper, Old World bearing. The Learjet and LearFan bespeak a designer unafraid of the unorthodox, with a lust for speed.

And then there is Jumbolair, a piece of aviation so special it demands close examination. I'm threading my way through the central Florida midmorning puffballs and setting up for an approach from the west. No mistaking the destination, just outside of Ocala—it's the only lighted, 7,550-foot-long, 210-foot-wide privately owned strip around. And just to keep from confusing the place with, say, Tampa International, it's the one with the 660-foot-wide berm at one end to deflect jet blast. Any jet may drop in, mind you, since the reinforced runway is able to accommodate 747s. There's also an east-west grass runway for the fun of it.

For a time a brace of 707s lived here. Two were outfitted as passenger carriers while the third was a cargo hauler—an ark, actually. The airplane made runs to Africa to fill the pens here with 98 elephants, two rhinos, and some 3,000 alligators and crocodiles, including



DAVID CLARK

*A revolutionary safety system designed to protect aircraft from inflight explosions following engine fires has been patented by Sayed Abdel Rahman Hassan Shoaib of Egypt. According to the November 3, 1997 issue of the Egyptian Gazette, his device will "automatically dismantle" wing-mounted engines and fuel tanks in the event of a fire. The inventor explains: "Engines usually self-explode in one to ten seconds in mid-air. The new device is installed into the cockpit and throws away the flaming engines and the back fuel tank. Another wing automatically works to turn the plane into a gliding aircraft, while giant balloons appear from the back of the plane to help reduce its speed. When the speed reaches 400 kilometres per hour, which is the usual speed of a helicopter, rotoring blades unfurl on the two wings to turn it into a helicopter, enabling the pilot to steer and make a safe landing."*

Gomic, an 18-foot monster from Australia. There was also once in residence a 450-pound silverback gorilla named Mickey. This being horse country, there are also three stables and seven paddocks.

Nearby is the convention center, which can seat 400 at a formal dinner or up to 1,000 for cocktails. The faux colonial manse is a comfy 7,600-square-footer with five bedroom suites, gourmet kitchen, and large sitting and dining rooms. A covered walkway leads to the ballroom and pool area, and near the pool is the key artifact: a private gym, freestanding and fabulously equipped.

Jumbolair was created by Arthur Jones, a tough-talking, chain-smoking eccentric with a penchant for airplanes, exotic animals, and young wives (his first five were teenagers when he married them). His motto was "Faster airplanes, younger women, and meaner crocodiles." Having invented the Nautilus line of exercise equipment, he was rich enough to indulge those interests.

Jones also designed physical rehabilitation equipment, and the Ocala

property was part of the grand scheme. To build interest in his rehab products he'd bring in doctors from all over the country, wine and dine them, and let them ogle the animals. After giving them product demos, he'd 707 the docs to a Mexican resort before jetting them home.

But business and love can be fickle. Jones exited Nautilus in the 1980s and, after a divorce settlement, wife number five, Terri Jones Thayer, became Jumbolair's laird. The Boeings are gone, as is the wildlife. Mickey the gorilla died of a stroke years ago, while Gomic munches on at a St. Augustine alligator farm. Jones' ex remarried and moved to Sarasota, where she is raising two youngsters. Although type-rated in the Cessna Citation, Boeing 707, and 747, she has little time to play with airplanes these days. And so, last fall, she put Jumbolair on the block. All 550

acres can be yours for \$11.5 million (rhinos not included). Call (941) 388-1539.

—William Garvey

### **Why We Have Harriers: A Bar Story**

Looking out of place in a bar full of clean-cut aviators in olive-drab flightsuits, Terry Haven, a bearded civilian in a shirt and tie, addressed the China Lake Naval Weapons Test Squadron All-Officers monthly meeting in California last December: "If you came today to hear about the F-22 or the Joint Strike Fighter or the A-12, wrong briefing."

Yes, Haven intended to discuss advanced aircraft concepts, a subject he deals with daily as head of China Lake's JSF program team. But here in the Barefoot Bar, he planned to turn back the clock a quarter-century to tell a story that has rarely, if ever, been told before.

Behind him, displayed next to the take-out pizza, were four models of strange aircraft. Connoisseurs of the obscure would have recognized one of them as the unsuccessful XfV-12A, a supersonic

vertical/short-takeoff-and-landing fighter/attack craft built by Rockwell in the mid-1970s. But the other three were making their first public appearance.

During the late 1960s, Haven recalled, "the feeling was that propulsion technology had progressed to the point where we could build a vertical-lift aircraft." The Navy asked for ideas for V/STOL attack aircraft. Four teams came up with concepts.

The Naval Aviation Test Center at Patuxent River, Maryland, proposed a derivative of the Douglas A-4 attack jet with direct-lift engines and diverter nozzles conceptually similar to those of the Soviet Yak-36 Forger. The Naval Air Development Center in Warminster, Pennsylvania, envisioned a larger aircraft with four lift fans in wings like those of the F-106. Rockwell, meanwhile, took an airframe based on components of the Douglas A-4 and McDonnell F-4 and fitted it with augmented-thrust wings that generated lift via air bleeding through holes in the wings and canards. "It was a tremendous idea," recalled John Lamb, "and it looked really, really good on paper. But neither the Navy nor Rockwell could make it fly."

Lamb, an energetic man who looks a little like Jonathan Winters, was in charge of China Lake's entry in the competition: a compact airplane with canards, two lift fans in the wings, and thrust vectoring at the rear. Although this was arguably the most prescient and, at least according to Lamb, the most plausible of the four concepts, the Navy chose to go with augmented-thrust wings. When the Rockwell prototypes fizzled, the Navy junked the domestic program and bought British Harriers.

Lamb wistfully examined the China Lake model one last time before leaving the bar. "It's a shame we didn't build it," he said. "We were headed in the right direction."

—Preston Lerner

CHAD SLATTERY



# The Art of Air Advertising

If you lived in Chicago in the late 1800s and had a day off, you could have spent it at an amusement park on the corner of Cottage Grove Avenue and 50th Street. The park was run by the Gabriel Yon Balloon Company, and to get people to buy a ride on its balloons, the company distributed posters illustrated with drawings of a mustachioed aeronaut named Captain Julhes and three tethered balloons in an open-air square rimmed by American flags. The poster boasted that the balloon company was the “only enterprise of this kind in America” and that, weather permitting, “daily captive ascensions” would be made to a height of 1,300 feet from 10 a.m. to 10 p.m. The poster did not mention the cost of an

ascension, but it did advertise that “grand concerts by a ladies orchestra” would be performed every afternoon and evening.

The Gabriel Yon Balloon Company is long gone, but its charming poster now belongs to the National Air and Space Museum. It’s part of a collection of 1,200 aviation posters—dating from 1879 to the present—that has been divided into four broad categories: lighter-than-air, airmail, air transportation, and military aviation.

When looked at as a whole, the collection provides an overview of the history of aviation, as well as the history of advertising. But it is also a collection of beautiful individual images—shiny airliners flying through heavenly skies over lush landscapes. “The ones that appeal to you are the ones that affect you like fine art,” says Joanne M. Gernstein London, the curator who oversees the collection.

“The posters get across in a flash the idea of what the airlines wanted you to think about aviation,” says London. “Early airlines tried to convey a sense of modernity and safety.” A poster published around 1937 by Imperial Airways, a now-defunct British airline, features an enormous flying boat with the caption “One of the 28 new 200 miles an hour two-decker Empire flying boats.” An ad for the Czechoslovak Air Transport Company has a painting of a three-engine propeller aircraft, noting that “three-engined aeroplanes will carry you quickly and safely to your destination.”

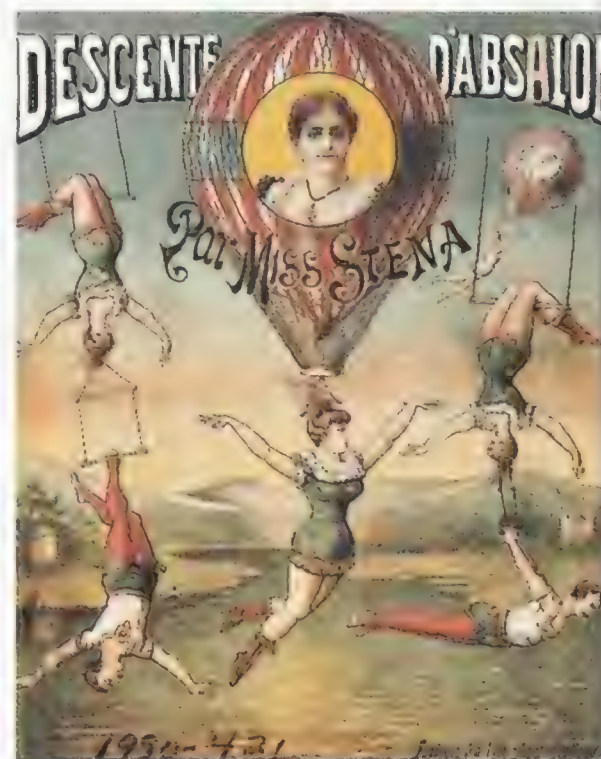
Airlines weren’t the only aviation organizations that used posters to advertise their services. The organizers of an early 1930s air meet in New Jersey issued a poster announcing “stunting, bomb dropping, Army and Navy maneuvers, and autogiro exhibitions.” Admission was 50

cents. The poster for an air circus held on October 5, 1947, touted performances by aerobatic champion Beverly Howard as well as “parking space available for white and colored.”

Though storage space is tight, the collection continues to expand. London says that she receives an average of one phone call a week from someone wanting to either donate or sell aviation posters. It is Museum policy, however, not to



NASM (2)



The collection includes a late-1800s poster advertising trapeze artist Miss Stena, who performed her act while suspended from a balloon, and a mid-1930s Eastern Air Lines poster urging “wise birds” to fly south.

purchase artifacts, and not every poster offered is accepted. “We must be sure that we don’t already have a particular poster,” says London. And even if there is no duplication, the poster must have historical significance.

It is London’s job to ensure that the collection is balanced, and since the majority of the posters are from foreign airlines, she is always on the lookout for U.S. airline posters. When the

Washington Airline Society, an organization dedicated to preserving the history of airlines, learned that the Museum was accepting artifacts, it recently donated 123 posters, many of which it acquired after the demise of flagship carrier Pan American Airlines in 1991.

Before the Museum's posters can be viewed by the public, they must undergo a lengthy and delicate preservation process that involves cleaning, humidifying, flattening, and encasing them in polyester film. By the end of the year, digitized images should be available to researchers, who will be reminded of the inevitability of change. A poster that Pan Am printed in the late 1950s to advertise its flights to Paris depicts a French waiter and a gendarme jointly raising a glass of wine in a toast. The caption reads "Jet Clipper Service Daily Via Pan Am. World's Most Experienced Airline."

—Tracy L. Scott

### Investigate the NTSB

Only days before the National Transportation Safety Board would be convening a very public hearing in Baltimore, Maryland, on the TWA Flight 800 crash, hundreds of NTSB staffers and retired employees gathered at the National Air and Space Museum to view the unveiling of a new exhibit honoring the board's role in advancing aviation safety. In contrast to the hearing, one of the most visible and media-covered of such events ever held, this was a private gathering over coffee—and well under the media's radar. Describing the exhibit as reflective of the board itself, Museum director Don Engen said the collection of displays is "small, but packs a big punch."

Ever since President Lyndon Johnson signed a bill establishing the independent agency in 1967, the board has embraced its mission with a uniquely low-key brand of tenacity. Much of its work is done quietly, with most recommendations on aviation safety conveyed directly to its principal client, the Federal Aviation Administration. But the relationship between the two agencies has been punctuated by numerous occasions when the NTSB felt the FAA was unresponsive. When that has happened, the board has frequently jumped onto center stage and yelled loudly enough to make the front page.

Visitors can view the tools of the trade, including a "go-bag," described as a typical collection of what an NTSB accident investigator takes along when examining a crash site. Also on display are examples of failed components such as engine valves and turbine disks, with photomicrographs that reveal the causes of such failures.

Many past recommendations are evident in the form of significant safety improvements: ground proximity warning indicators, fire suppression advances, and strip lighting for cabin floors to lead passengers to exits in smoke-filled spaces. Although that yellow plastic police tape keeps most of us from getting a firsthand look at the science of aircraft accident investigation, this new exhibit in the Air Transportation Gallery is the next best thing.

—George C. Larson

### Museum Calendar

*Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700; TTY (202) 357-1729.*

**February 28 Teachers' Workshop.** To shape an oral history project for students in grades 5 to 8, teachers will interview Tuskegee Airmen and review sources from that period. Teachers will receive lunch, free instructional materials, and a 10 percent gift shop discount for the day. Class fee: \$15. Registration deadline is Feb. 16; call (202) 786-2106.

**National Air and Space Society Lecture.** "Doolittle's Tokyo Raiders." Two pilots, Major General David M. Jones, USAF

(ret.) and Colonel William M. Bower, USAF (ret.), will talk about their participation in the famous April 1942 attack on Tokyo. The daylight raid on important military targets began with the launch of 16 U.S. Army Air Forces light bombers from the 500-foot-long deck of the U.S.S. *Hornet*. After Jones and Bower completed their missions, they bailed out over China and escaped enemy capture with the help of the Chinese. To purchase tickets to their lecture, which are \$10 for NASS members and \$15 for non-members, call (202) 357-3762. The proceeds will help support the construction of the Museum's new Dulles Center. Langley Theater, 8 p.m.

### Curator's Choice

Once a week a Museum curator will give a 15-minute talk about a particular artifact or item of interest. Feb. 18, George Carruthers' Lunar Observatory; Feb. 25, Redtails: Tuskegee Airmen and the P-51 Mustang. Meet at the Gold Seal in the Milestones of Flight gallery at noon.

### Flights of Fancy

Each Saturday in February is storytime for children ages 3 to 7. In celebration of Black History Month, Museum staff and volunteers will read stories about such African-American aviators as Bessie Coleman. Gallery 109, 2 p.m.



*On a Thursday morning last October, Brigadier General Charles E. "Chuck" Yeager once again sat in the cockpit of a Bell X-1. On October 14, 1947, Yeager flew Glamorous Glennis on the first supersonic flight, and now the aircraft hangs from the ceiling of the National Air and Space Museum. Yeager, who was in town last fall to give a lecture, arrived at the Museum hours before it opened. A cherry picker lifted him level with the cockpit floor (the hatch had been removed earlier). As Yeager climbed in, a cheer burst forth from a crowd of some 50 onlookers. "Since they put the airplane in the Museum, that's the first time I've been in the cockpit," said Yeager, who stayed aboard for an hour before riding down on the cherry picker.*

## Getting There Is Half the Fun

**M**y last trip into space was my first on a Russian rocket—the first time, in fact, any U.S. astronaut traveled aboard the Russian Soyuz. How much that trip would differ from my shuttle journeys became clear even before I reached the launch pad.

On our way from the cosmonaut suit-up area to the spacecraft, the driver of our van pulled off the road and stopped. At this very spot on April 12, 1961, cosmonaut Yuri Gagarin had asked his driver to pull to the side of the road so he could relieve himself one last time before boarding the spacecraft. And, since Yuri made it back in one piece, every cosmonaut who has flown to space since has stopped in the same shady spot and taken a moment to pay tribute to him. The tradition is honored even by women. Elena Kondrakova got off the bus with her Mir 17 crewmates even though she was not able to participate in the ritual.

What Americans think of as superstition is simply a part of life in Russia. The cosmonauts do not bring their families to view the launches, for example, because they consider that bad luck. Instead there is a champagne toast at the crew quarters in Leninsk to wish them well just before they board the van for the 40-minute ride to the cosmodrome. A few moments are spent sitting in silence as part of this ritual gathering—a practice thought to ensure the travelers' safe return.

A large crowd awaited us at the launch pad. Even though a Russian rocket once exploded on the pad, killing 169 people, our well-wishers had gathered just a few feet away from the launch vehicle, which was pluming oxygen vapor, a sign that it was fueled and ready for launch. NASA, with characteristic caution, prohibits all but the White Room and flight crew members from coming within miles of the space shuttle once fueling begins, but our audience did not seem the least concerned by the potential "bomb" breathing nearby.

I remember the morning perfectly. It was sunny but bitterly cold—well below



NASA (2)

freezing with a strong wind. A space shuttle would never be launched in these conditions. I knew the lack of solid rocket boosters would make the vehicle somewhat impervious to low temperatures, but the wind worried me a little. I questioned Gennady Strekalov, our flight engineer, about the wisdom of launching on such a day. He told me that the only weather condition that would keep us on the ground was a hurricane.

From the platform base, we rode an elevator up about a hundred feet to board the spacecraft. The Soyuz-TM is made up of four modules, two of them accessible by the crew: a 230-cubic-foot living module, which contains a toilet, food, water, and additional clothing, and a 124-cubic-foot descent module. After we entered the living module, Strekalov was the first to climb down through a hatch into the descent module since it was his responsibility, as flight engineer, to turn on the working light, the control panel power, and the power for pressure suit ventilation. There was barely enough room in the tiny space for the three men in pressure suits, but throughout the

launch, that's where we remained with the hatch closed—not a place for the claustrophobic. The living module was forbidden to us until we were safely in orbit because only the descent module is equipped with a parachute.

Five minutes before launch, we closed our visors. Just as he would have done during an American launch, the capsule communicator from the launch center gave us a call at L-1 minute to tell us that everything was on schedule. Then he handed over control of the spacecraft to our commander, Volodya Dezhurov. When Dezhurov told ground control that we were prepared for launch, I finally knew for sure that I would leave Earth in a Russian rocket.

The engines started. Soyuz engines produce almost a million pounds of thrust to push the rocket, the spacecraft, and us off the ground. There was no "twang," or rocking, as there is on the shuttle. This is an old-fashioned rocket whose engines thrust through its center of gravity. (The shuttle rocks forward at engine start because its main engines are located above the center of gravity.) The engine was not as loud as the shuttle engines and the vibration was less pronounced.

During the first-stage flight of the space shuttle, the solid rocket boosters produce sound and vibration almost like a giant popcorn popper. But after the SRBs are expended, the shuttle ride is like being pushed by a powerful but quiet electric motor. The three-stage Soyuz doesn't ride as smoothly as the shuttle, but the peak acceleration—approximately 3 Gs—is about the same.

My major responsibility on the flight, in addition to backing up the commander in checking out and verifying spacecraft systems, was the control of our communications systems. These included radios and internal cameras. One of my jobs was to keep track of impending communications passes and power up the radios shortly ahead of them.

After the cutoff of the Soyuz third stage, we were suddenly in weightlessness. The noise and vibration



*Astronaut Norman Thagard and his understudy Bonnie Dunbar trained in Star City for spaceflights in the Soyuz-TM (for transport module). The Russian Soyuz rocket (opposite) has been launching spacefarers since 1964.*

were gone, as was the sensation of speed. It is difficult to describe the exhilaration of riding a rocket into space. You go from zero to 18,000 mph and from sea level to 200 miles up in about nine minutes, and the elation you feel is a combination of things: the thrill anyone experiences from power and speed, whether produced by a race car, a fighter jet, or a rocket; the strange repose of free-falling, once orbital speed has been achieved; and the immense relief of having survived a dangerous passage.

I have never worried too much about the dangers inherent in rockets. On the first space shuttle mission I flew following the *Challenger* accident, I had a few moments of anxiety before liftoff. But throughout the Soyuz launch, I was even more relaxed than usual. Just before the engines started, I had looked to my left toward Strelakov and recalled that a Soyuz had blown up under him once as he sat, just as we were, awaiting liftoff. Strelakov is living proof that the Russian emergency escape system works.

Of course it would be impossible to experience the tremendous physical forces of a rocket launch without an awareness at some level that something could go wrong. The Russians, who are wise in matters of psychology, must know this. The position of capsule communicator is always filled by the Soyuz instructor who oversees the long training program for the mission, and his voice from the ground, periodically

informing us that everything was okay, helped us relax and enjoy the flight.

On my first spaceflight, my crewmate John Fabian let out a war whoop as we arrived in orbit. I'm too restrained to yell, but I knew how he felt.

Within the first hour, we executed the procedures to place the docking "stinger" in its initial position. The stinger is part of the mechanism that must mate with the docking port on the Mir space station. A couple of the commands necessary for this procedure were mine to make by pressing certain buttons on my control panel.

During the second orbit, we ran important tests of the motion control systems. The Course system is the radar-based rendezvous and docking system that would enable us to link up with Mir. The test results were entirely normal, and we were another step closer to our link-up, which was just two days away.

The next scheduled event was the first of two maneuvers that would direct us toward our rendezvous with the space station. During the fourth orbit, Dezhurov and Strelakov made the computer inputs to fire the Soyuz's main engine for rendezvous, a 660-pound-thrust approach engine. As with such firings of the space shuttle's orbital maneuvering system engines, we felt a gentle acceleration. My crewmates set up a kind of "barbecue" mode that pointed the solar batteries toward the sun for optimal power generation and slowly spun the spacecraft around the pointing axis.

I was able to perform all of my duties despite feelings of stomach awareness. This is a feeling, short of nausea, that is a prodromal symptom of space motion sickness—something I, as an astronaut and a doctor, have both experienced and treated. Although my symptoms were

mild, I asked Strelakov to inject an analgesic and anti-nausea drug into an I.V. in my arm just before the sleep period. When I awakened, the symptoms had disappeared.

I had never been on a rendezvous mission before, but the Russians were obviously expert at it. We first had to adjust our course by twice firing the approach engine. Both times, Dezhurov turned the whole spacecraft by firing smaller attitude correction rockets to point the approach engine in the correct direction prior to firing it. We all watched expectantly for capture of the space station by the Course system so that automatic approach could proceed.

Seeing the station for the first time must have been a thrill for Dezhurov, a rookie commander. It was even more enjoyable for me, since I wasn't the one who had to worry about a failure of the automatic docking system. In the event of such a failure, Dezhurov would manually fly us to a docking with Mir. Strelakov, veteran of five spaceflights, was the picture of cool professionalism.

As it turned out, however, docking was totally automatic. There was a jolt upon contact, but it was not so hard as to cause alarm. We were actually mechanically attached to the station, but final mechanical and electrical union took close to 20 minutes.

I tried to comb my hair in anticipation of going on board. It was a useless gesture. My hair was sweaty from the suit and it had been cut so short by the Russian barber in Leninsk the day before launch that I wasn't sure I would ever need another haircut.

At last, Dezhurov opened the hatch and went up to the living module to make sure that the seal between our spacecraft and the Mir station was tight and no air was escaping. He cracked the hatch just wide enough to pass through the Russian and U.S. flags we had brought. After a few minutes, the hatch was fully opened and I was given the honor of being the first to go aboard Mir.

There I was handed a small tray to which was attached bread and salt, a typical Russian greeting to a new arrival. Elena Kondrakova, the Mir 17 flight engineer, gave me a big hug, and I met Sasha Vikorenko, Mir 17 commander, and Valery Polyakov, cosmonaut researcher.

I marveled at Polyakov's appearance. He was obviously physically and psychologically none the worse for wear despite having set the new record for single-flight duration: fourteen and a half months. I was suddenly impressed at how lucky I was to have the opportunity to be on Mir, where I lived for the next 111 days.

—Norman E. Thagard

**H**ere he comes!" The shout turns heads among the crowd on the roof of the huge hangar. Fingers point. A black shape approaches—low, stately, enfolded in sound; it curves overhead in a shallow bank. Pilot Rogers Smith has promised a flyby in the SR-71 as he returns from a test mission that has taken him, in the space of an hour and a half, over several states—room that he needed just to get turned around at three times the speed of sound.

The flyby draws soft gasps from onlookers, as fireworks often do. Familiar as it is, one always feels about this airplane as if one had seen something from another world, like a fallen angel or a pterodactyl. For the people at the Dry-

den Flight Research Center who have left their desks and machines to come out here—people who work around experimental airplanes every day—the thrill never gets old. They are people who were born to look up.

The Mojave Desert is a good place to do it: Here the world seems to be almost all sky. The earth is no more than a shallow sand-colored pan, girdled by a low rim of mountains, but over it arches, vast and generous, the bright imperial air, already incandescent with summer heat as the midmorning sun climbs above a few flounces of cloud.

At the desert's western end is a vast flat plain. This is Rogers Dry Lake—dust pretending to be water. Beside it stand, incongruously, the flight test cen-

ters of NASA and the Air Force. They form a city in miniature, with an odd urban wildlife of crows hopping and croaking and battenning on roadkill, and coyotes trotting, alert and long-shadowed, across early-morning roads. From time to time the stillness parts for the distant crackle of jet engines or the always-startling THUN-THUNP of a sonic boom; then it closes, like parted water, behind them.

The place became this place in 1946, when the National Advisory Committee

*Dryden used the accommodating aft fuselage of one of its SR-71s to test fly a scale model linear aerospike rocket engine for the single-stage-to-orbit X-33.*

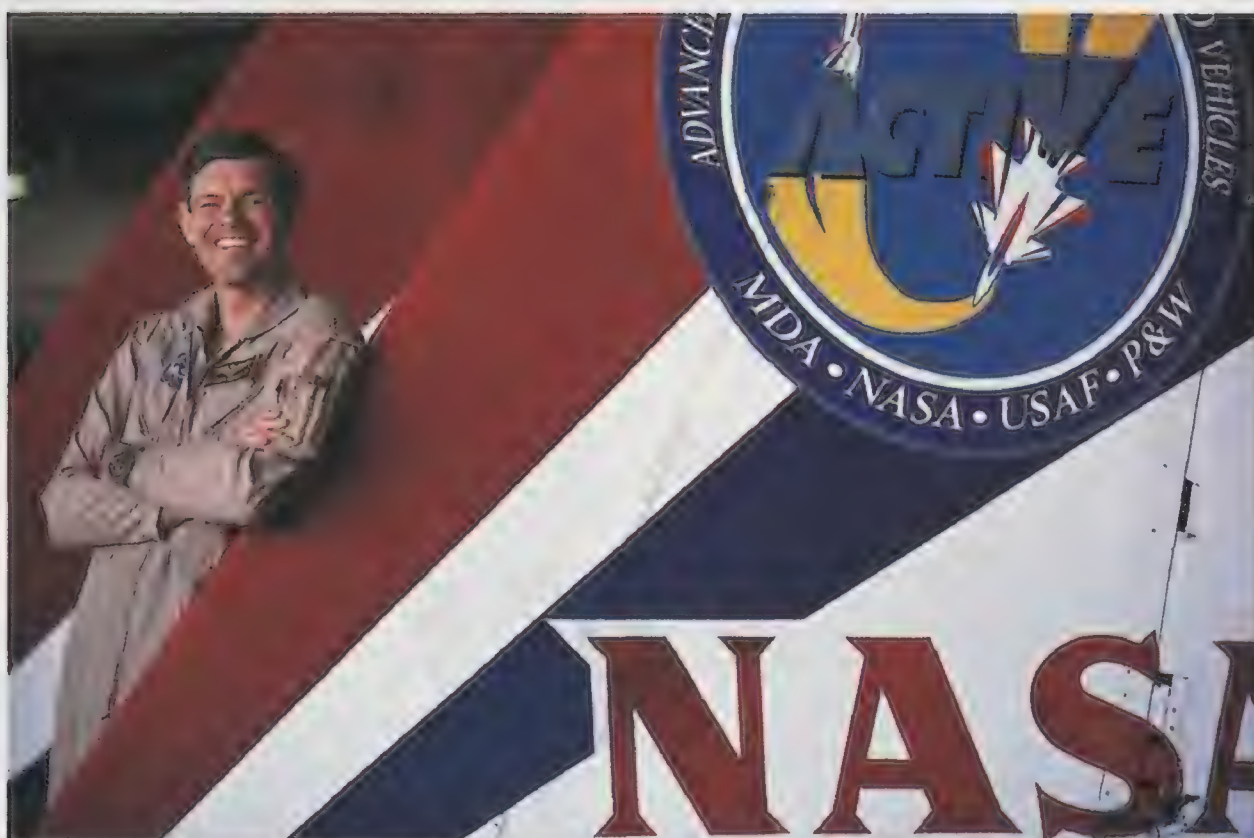
by Peter Garrison

*Photographs by Chad Slattery*

# Seven Days at Dryden

Meet Pathfinder, ACTIVE, DarkStar, SRA, Mothership, X-38, and all the other extraordinary creatures at America's premier flight research center.





member. They may last weeks or years, achieve fame or end in obscurity. A week spent at the facility demonstrates that the full spectrum of Dryden's esoteric work, and of its impacts on aviation, is bewilderingly broad.

**A**t nine on Monday morning two dozen members of the Systems Research Aircraft team have assembled for a weekly briefing. The meeting room is dull and generic, with bland acoustic tile ceilings, two faux-wood panelled walls, and two textured with a puce fabric to match the chairs. No filmmaker would ever stage a flight research briefing on a set like this.

The SRA is a highly modified F-18 with a digital fly-by-wire flight control system. It carries powerful onboard computers and data acquisition hardware to

on Aeronautics—NACA, NASA's precursor—scenting the fumes of the impending Jet Age, selected the remote spot for its most secret and advanced testing. At first, the NACA staff consisted of 13 people. They arrived after the last blaze of September; otherwise, they would have thought they had died and gone to hell. Winter was bad enough. Dust carried by the often violent winds got into the bedsheets and the eggs and into the adding machines operated by the young women who were the digital computers of that era. But the small staff worked well. On October 14, 1947, almost a year to the day after the arrival of the first skeleton team, the X-1 outran the roar of its own rocket engines.

Rogers Dry Lake has remained a myth-making place. It echoes with successive maxima of speed and height; with streams of X-planes, freakish and beautiful machines like that original X-1, the spike-nosed X-3, the X-15, the XB-70, and, later, the Lunar Landing Research Vehicle and the space shuttle.

Long operated as the NACA High Speed Flight Research Station, the facility became NASA's Flight Research Center in 1949. It underwent another name change in 1976, and now it is called the Dryden Flight Research Center, for Hugh Dryden, NACA's director during the 1950s. (DFRC, as opposed to the famous Edwards Air Force Base, is an entity of somewhat obscure outline. Mere names do not always mean a lot, but in

*Is research pilot Ed Schneider (above) the last of his kind? The trend is toward pilotless aircraft with an emphasis on spacecraft—like the scale model of the X-38 (below), the technology demonstrator for the space station's crew return vehicle, here shown testing the ram-air parafoil landing system.*

this case the distinction between flight "test" at Edwards and flight "research" at Dryden is worth holding on to. Edwards tests airplanes; Dryden tests ideas.)

The ideas are embodied in airplanes, though, and Dryden owns a fleet of them, including two SR-71s, several F/A-18s and F-15s, including some highly modified hot rods, a B-52 drop plane, and the shuttle-carrying 747. Others, the debris of past test programs, stand in hangars or collect dust on concrete pads, to be viewed by tours of local high schoolers. Still others, like the remotely piloted finless X-36 and Lockheed's Dark-Star, which resembles a winged portable CD player, are the property of various manufacturers and contractors and remain here for only a time, using Dryden's facilities and expertise for flight test support. DFRC experiments may take place at low altitude and a few hundred miles an hour, or 15 miles up at Mach 3. They may originate with a manufacturer, with another NASA center, or with an enterprising Dryden staff

JIM ROSS/NASA



test small systems and software. The airplane's systems are duplicated in a permanently hangared "iron bird" on which installations are mocked up before being placed on the test aircraft.

The present program involves a rather mundane contraption: a device used to shake wingtips in order to investigate the kinds of structural vibrations that, given the right combination of unlucky resonances, could tear an airplane apart. Like other SRA projects, this one involves not only the device itself but various electronic boxes that operate it and other ones that record its performance and send a stream of telemetry back to the ground. Preparation for such tests takes weeks or months; in contrast, the test flying itself may last only an hour or two, and the desired information may be obtained in just a few seconds. The



*Chief research pilot Rogers Smith has the best corner office at Dryden—the cockpit of a Blackbird.*

principal work of flight research, therefore, consists of wrestling all the details into place before the airplane actually takes off.

Joel Sitz is the SRA project manager. A blond man who somewhat resembles actor William Hurt, he allows the chief engineer, Dave Voracek, to do most of the talking. The stocky, youthful Voracek begins by running through the week's discrepancy reports, short forms that are projected one by one on a screen behind him.

Acronyms fill the air as Voracek and operations engineer Dave Webber exchange opinions on the importance of a malfunctioning light. The light is supposed to show if the shaker is operating, but it's not working properly itself. Ignore it, Voracek says; it's of no consequence—the pilot can tell if the shak-



er is operating. Webber thinks it's unwise to ignore the light without carefully analyzing the failure's implications in conjunction with certain other possible failures. Their personalities are opposed: Voracek confident, intuitive, freewheeling; Webber cautious, skeptical, analytical. Their exchange has an edge of controlled tension. Later, Webber will remark that "project managers like to say yes."

The discussion shifts to another potential problem. The gears driving the device's slotted rotor were damaged because of a voltage spike. They are being replaced, and Voracek is satisfied that the problem has been corrected. But Webber pounces again. "What if the gears failed in flight? Could the rotor freewheel in such a way as to excite unwanted frequencies? Could it shake itself off the airplane?"

Another speaker from the floor enlarges upon this apocalyptic scenario. "What if it fell off and the chase plane ingested it?" Perhaps this is a sarcastic joke at the cautious Webber's expense—it's hard to tell.

Voracek is visibly impatient with far-fetched suppositions, but they are, after all, the reason for these sessions. Flight test, once a proverbially dangerous activity, no longer is, because experience has taught that the way to avoid the unexpected is to expect the unlikely.

At 9:30 the SRA team loses the room to another group. Unresolved matters will be settled in private discussions later.

The next meeting is a pre-brief for an F-15 ACTIVE flight that will take place tomorrow. Test pilot Ed Schneider presides over a clipped give-and-take.

"Range?"

"We'll be in NASA Two tomorrow."

"Control room staffing?"

"Mike's controlling."

Schneider, a former Navy helicopter pilot whose parents had hoped he would be a doctor, is an elfin-faced man of 49. Clearly happy in front of an audience, he runs the flight briefing with an undercurrent of dry wit; his blue eyes widen as he warms to a joke. If David Letterman were a test pilot, he might run briefings like this.



JIM ROSS/NASA

and high-thrust engines with swivelling exhaust nozzles. Structurally it's a little weaker than a stock F-15 and is limited to 5-G maneuvers, but it's controllable at very high angles of attack and, like the F-15E, develops so much thrust that it can accelerate while climbing straight up.

The current experiment is called HISTEC, for High Stability Engine Control. Inlet air pressure sensors on the face of the right engine will send information to a processor that looks at the position of the throttles and controls the fuel supply to the engine accordingly. The aim is to eliminate compressor stall, the flow breakdown that occurs when a pilot asks a jet engine for so much power that it can't get enough air into its compressor and the engine gasps. The possibility of compressor stall limits the pilot's ability to use high power while maneuvering; if

Helicopter pilots were the lowest of the low in the eyes of Navy jet jocks, but Schneider takes malicious pleasure in the fact that most of his squadron buddies are civilians flying cars and desks now—"eating dust"—and he's flying the SR-71. When he's short on proficiency hours, he can take up one of the F-18s for a little fun.

The ACTIVE—Advanced Control Technology for Integrated Vehicles, which is on loan to Dryden from the Air Force, is a radically modified F-15, with a pair of F-18 stabilators added as canards to the shoulders of the air intakes,

*Dryden's stable contains an eclectic mix of aircraft. The center's F/A-18s have worn many saddles; above, an F/A-18 in HARV livery (High Alpha Research Vehicle). The remotely piloted X-36 Tailless Fighter Agility craft (opposite) bares its soul. One of Dale Reed's projects is a Dryden classic: the HL-10 lifting body (below).*



the engine can be protected against it, pilots will be able to run engines closer to their design limits for longer periods.

Schneider reviews the 26 "cards" that are the script for tomorrow's mission. Many of the test points require combinations of speed and nose-up angle that even this superplane cannot achieve in normal flight. To reach those points, Schneider will roll the airplane onto its back at 20,000 feet and hit the point while plunging toward the ground inverted at 400 mph, pulling 5 Gs.

**T**est pilots have traditionally been kingpins in this world, but that's changing, and the test pilots frankly don't like it. Increasingly, ground-controlled or even fully autonomous airplanes—robot craft that perform their missions without human intervention—are being used for test work. The attractions are evident. Since they don't have to carry a pilot, they don't have to be as large or support as many redundant systems as a manned aircraft.

There have been some shining successes with unmanned test vehicles—most recently, the maimed-looking X-36, a baby jet deprived, for reasons of stealth, of its vertical tail. There have also been some conspicuous failures, such as the autonomous Lockheed DarkStar that pitched up, stalled, and crashed before the aghast eyes of its supremely confident programmers in April 1996.

"The trouble," says the boyish Rogers Smith, who is DFRC's chief research pilot, "is that people talk as if you don't need as much redundancy if you don't have a pilot. But actually you don't want to lose a pilotless prototype any more than you want to lose a piloted one. So it turns out you need all the safeguards anyway. These guys are so overconfident—they don't even see the need for a backup remote control system, let alone a pilot. We were just lucky DarkStar didn't hit a hangar."

Despite the still-fresh memory of the DarkStar crash, remotely piloted and fully autonomous vehicles are here to stay, in part because, even after the testing is over, the eventual production versions will themselves be pilotless. And



you really can build and test pilotless "faster, better, cheaper"—as NASA's new mantra dictates. Ask Dale Reed.

Reed ceased to be a NASA employee in 1985, when he went to work for Lockheed and later for a Dryden contractor called Analytical Services and Materials, but he still has an office at Dryden, as he has since 1953, when it was the NACA High Speed Flight Station and he had arrived fresh out of the University of Idaho. Reed is the quintessence of the "old Dryden," where the staff and budgets were smaller and the wild whims of a few inventive people were as likely to set the course of aeronautical research as were industry requirements and government programs.

Reed was one of the creators of the original lifting body program; he used a hopped-up Pontiac to tow a plywood test article that resembled a finned potato across a dry lake bed (see "The Legacy of the Lifting Body," Apr./May 1991). Those makeshift tests proved the viability of the lifting body idea and launched a years-long formal test program using air drops from under the wing of the venerable B-52, the same airplane that

had launched the X-15s. In the meantime, Reed, himself an accomplished radio-control modeler, was dropping new shapes from a 14-foot-span, radio-controlled balsa model called "Mothership." Mother is still flying today: with 28 years of service it is arguably NASA's most cost-effective research aircraft.

NASA decided not to use lifting bodies for crew recovery; instead, it went first to parachutes, then to the winged boxcar we call the shuttle. Lifting bodies sat on the shelf for two decades. But now they have a new lease on life, thanks to experiments Reed conducted in the late 1960s with "decoupled mode" recovery systems: A maneuverable lifting body flies back into the atmosphere from space but deploys a parafoil parachute for final approach and landing.

Reed, a tall man with glasses, thinning black hair and slightly stooped posture, walks around the X-38, a test airframe of NASA's space station lifeboat. "It had to be heavy to be realistic," he ex-

plains, slapping the whale-like white sides. "Some places the fiberglass is two inches thick. There are tubes full of lead shot to weigh it down some more."

The recovery sequence will be automatic. "The crew doesn't have to do anything," Reed says. "But the system has 800-mile cross-track gliding ability, and it'll be able to land anywhere—any open place of a few acres." In classic Reed style, he talked fellow experimenters into demonstrating a scale model of the whole system; it was pushed out of the baggage door of a Cessna, and Reed and his crew demonstrated automatic flight to a precision landing using satellite guidance.

Reed's head has consistently been one of Dryden's most fertile sources of ideas, including a survey airplane to fly around on Mars, powered by an engine running on a single fuel, hydrazine, that contains its own oxygen. He is also currently evaluating schemes for a VentureStar carrier, an airplane that could lug Lockheed's huge single-stage-to-orbit prototype around the way NASA's 747 does the shuttle. He unfolds a sheet bearing half a dozen bizarre designs,



JIM ROSS/NASA

nearly all involving surplus airplanes cut up and reassembled. One proposal has two B-52s spliced into a single huge airborne catamaran. All have problems, either of ground clearance or of aerodynamic interference between the carrier and its bloated cargo. "This would actually be the best one," he says wistfully, indicating a huge six-engine Antonov An-225. Unfortunately, only one exists, and it is not in Dryden's fleet.

**T**he preeminent requisite of a test pilot is not courage; it's precision. His job is to get an airplane to a certain speed, altitude, and angle of attack and hold it there for a few seconds, and to do this without ever making the two dozen people in the control room impatient.

Today Ed Schneider will get the HISTEC test points. The flight

*The aerodynamically busy F-15 ACTIVE uses vectored thrust, canards, and an advanced control system to research improved cruise and maneuvering capabilities.*

has been scrubbed twice, first because of a tropical low that brought rain and even a tiny tornado to the Mojave, the second time because of a minor mechanical problem with an engine pump.



Today looks good; the weather is perfect, the airplane is working. The flight will be long: three hours, Dryden's arbitrary limit, with several trips to an Air Force tanker loitering over the north side of the test range. Out on the burning ramp, the deafening whine of the engines of the F-15 and its F-18 chase rises as the two airplanes begin to taxi.

In the chilly NASA Two control room, amid the soft whir of computer fans and the patter of voices, rows of monitors display test data, images from optical tracking cameras, and even a black-and-white pilot's-eye view with the Head-Up Display superimposed upon it. Data from the test flight, some parameters being sampled a thousand times a second, will pour down from the airplane in a compressed and encoded stream; technicians in the control room

will quickly assess the quality of the data and either clear the airplane to the next card or ask for a repeat.

Once airborne, Schneider initially climbs to 7,800 feet. The ACTIVE, a sleek six-winged bug, gleams in the telescopic camera.

"You're cleared to 78."

"Pushing up to 78."

"Okay, we're takin' data."

"We're on condition here."

"Cleared to mil" [military power].

"Cleared to mil."

"Okay, going to mil."

"Push to mil."

"Okay, there's mil."

"We're counting."

"Takin' data."

"Okay, we're stable."

"There."

"Okay, cleared to the next point."

Schneider climbs to 20,000 feet; it doesn't take long.

"Cleared for idle."

"Coming to idle."

"On condition."

"Takin' data."

"Takin' data."

"Okay, complete. Cleared for mil."

"On condition."

"Complete."

"Okay, on to card six. Down to 5,000 feet."

Four miles above the ground a middle-aged 150-pound man is taking a 20-ton airplane on a tour of the corners of its flight envelope. He does this effortlessly; he may as well be sitting at a desk. The test points reel off routinely; only rarely does he have to repeat one, occasionally because he has slightly missed a difficult point but more often because there has been an electronic glitch in the telemetry stream. Schneider's voice, reporting each action aboard the F-15 and echoed by ground controllers, is as calm and firm at 4 Gs as at 1.

**T**he X-33, Lockheed's proof-of-concept prototype for its shuttle-replacing VentureStar, is intended to rise vertically from a remote launch pad at Haystack Butte, several miles from the Dryden and Edwards hangars, reach Mach 13 and 200,000 feet, and glide back to a landing in Montana or Utah. It is supposed to do this in 1999, but nobody outside of the Lockheed Martin public relations department thinks it will happen

that soon. The X-33 represents one extreme among Dryden projects. At the other pole are more modest and obscure programs, some of them pretty nearly one-man shows.

"If you feel strongly, you can do what you want here," says Glenn Gilyard. In his office, one wall is dominated by a large picture of an owl coming in for a landing; beneath it Gilyard has placed a caption saying, "The Ultimate In Variable Camber."

Gilyard has devoted years to wringing out of jet transports an extra one percent of fuel efficiency—worth hundreds of millions of dollars a year to the world's airlines—by subtly adjusting the positions of control surfaces in flight. He knows how to do it and has demonstrated his technique on an L-1011 tri-jet. The underlying idea is simple: Airplanes are most efficient at a certain combination of weight, speed, altitude, and center-of-gravity position—the minimum-drag design point—but they almost never operate precisely at that point. They are faster, slower, higher, lower, heavier, lighter, or somehow out of balance because of unavoidable randomness in the distribution of passengers, cargo, or fuel. By slightly adjusting the positions of control surfaces, Gilyard proposes to bring the minimum-drag point closer to where the airplane really is.

It's easy to do. On the new fly-by-wire airplanes like the 777 and the later Airbus airliners, all that's needed is a software change. On older airplanes, a few rigid pushrods would be replaced with ones whose length can be adjusted by small internal electric motors.

Gilyard has tested the system, optimized it, written the reports. Now he wants someone to use it. Curiously, aircraft manufacturers, the obvious exploiters of such a system, seem indifferent. Gilyard is going to try the airlines next. He has nothing to gain himself; the idea, the knowledge, the testing done under Dryden's auspices with government funds—all these are free for the taking. The problem is to find a company who will take them. Gilyard is perplexed but not yet discouraged. "A weaker person," he muses wryly, "would have given up."

Bill Burcham is another experimenter with a clever idea. It's called PCA, for Propulsion-Controlled Aircraft (see "Cleared for Landing," From the Field,

*Dryden veteran Glenn Gilyard (opposite) says, "If you feel strongly, you can do what you want here." Dale Reed (below, at right) and a co-worker show off Mothership, a radio-controlled carrier ship that has served Dryden for 28 years.*



Apr./May 1995). From time to time a large transport experiences a major flight control system failure that requires the crew to try to use engine thrust to steer the airplane. Most end up crashing. Some control is possible because thrust, in addition to pushing the airplane forward, also pitches it up and down if the axis of the engine passes below the airplane's center of gravity. Engines not on the airplane's centerline can also be used to swing the nose to one side or the other. It follows that the airplane can be controlled to some extent by manipulating thrust alone. Skillful pilots can barely manage to get a crippled airplane to an airport, much less make a safe landing; for a computer's unwavering attention and instantaneous responses, it's an easier matter. Burcham's team has developed software, tested first at Dryden on an F-15 and later on an MD-11, that controls engine thrust on a crippled airplane and has enabled pilots to make six landings without any use of flight controls. All were safe landings; the NASA test pilot reported that one of the MD-11 landings was as good as any he'd ever made in a normal airplane.

**J**ohn Del Frate and Jeffrey Bauer work for Jennifer Baer-Riedhart, the manager for ERAST—Environmental Research Aircraft and Sensor Technology—a program that is unusual in that NASA's role is that of a coordinator of a number of private initiatives. Their



goal is to develop remote-controlled airplanes capable of flying very high up—above 80,000 feet, where the density of the atmosphere is 1/30 that at sea level—and remaining on station for a very long time, possibly days or even weeks.

Extreme high-altitude flight involves special problems. Because the air is so thin, an airplane must move very fast in order to encounter enough of it to stay aloft. The airplane may be moving at 400 mph, yet feeling no more air pressure than it would at 60 mph at sea lev-

el. Even at low air densities, however, moving this fast requires considerable power. To collect enough oxygen to burn the necessary amount of fuel requires stringing several turbochargers together in a chain, while huge radiators are needed to dissipate engine heat.

The strangest, and so far the most successful of ERAST's projects, is AeroVironment's Pathfinder, which consists of a 98-foot-long transparent Mylar-covered wing and little else. Its six electric motors get their power from solar cells blanketing the upper surface of the wing. Pathfinder is so long and flexible that Bauer compares its flight through turbulence to a half-deflated air mattress floating on the ocean.

Pathfinder, which began its testing at Dryden but spent last summer flying in Hawaii, has climbed to a record 71,530 feet and, perhaps more significant, has made the transition from testing to doing actual scientific work. Its successor, the 200-foot-span, 12-engine Centurion, is expected to reach 100,000 feet, and a still-theoretical descendant, Helios, will store enough energy during the day to keep it aloft for weeks.

*The unmanned high altitude-reconnaissance craft DarkStar crashed in 1996, causing some wags to dub the site DarkSpot.*

DEPARTMENT OF DEFENSE



*Dryden's Environmental Research Aircraft and Sensor Technology program includes the solar-powered Pathfinder (left), which recently set an altitude record of 71,530 feet. Its successor, Centurion (a model of which soars at right), will have 12 electric motors and a wingspan of 200 feet.*

One of the problems of designing airplanes to operate at extreme altitudes is that air flows differently there, and it is unfortunately very difficult to achieve the proper combination of high velocity, low density, and low turbulence in a wind tunnel. Dryden therefore plans to launch a glider called Apex from a balloon at 115,000 feet. It will be carried aloft hanging nose-down like a bungee-jumper, then dropped. With the help of a rocket thruster—aerodynamic controls would not be enough in the near-vacuum—it will level out and spiral down, collecting data on the behavior of wings that feel as though they're barely moving but are traveling at nearly the speed of sound. The information will be used to validate methods of predicting wing behavior with computers, and these will in turn be used to design future high-altitude airplanes. Does something about the unconventional launch method, reminiscent of something modelers might attempt, seem familiar? Right—it's a Dale Reed idea.

**A**t 4 p.m. Dryden starts to shut down. The engines on the ramp are silenced and the buildings begin to empty. Miniature traffic jams develop in the town of Edwards and, soon after, some 20 miles to the west, at the edge of fast-growing, mall-flavored Rosamond. Back to the ordinary world of family, dinner, television, sleep. The center, spotlight and populated by guards and small rustling desert creatures, waits for its pilots, technicians, scientists, and administrators to sail back in the morning as they have for the past half-century. Maybe tomorrow will be one of those days when somebody scanning a computer print-out will say "Hey, look at this!" People will gather around, peer over shoulders, say "I'll be damned!" and "Yup, that's it!" And another avenue of discovery will open up. —



# Gone but Not

An album  
of exceptionally  
obscure  
warbirds from  
the collection of  
Major Howdy  
Bixby.

Text and illustrations  
by Bruce McCall

## **Canard-et-Chicane Bomber, Dadaist Free Squadron, France**

Not to be confused with the Artists & Models Escadrille, also born of patriotic desperation in the glorious hopelessness of May 1940. The Dadaist Free Squadron flew its own Canard-et-Chicane 607-B, bought from L'Armée de l'Air via a crooked cabinet minister for 100 francs. The all-volunteer Dadaists' "nonsense tactics" of bombing French troops, carrying no bombs, or simply staying parked on the tarmac for days befuddled Nazi attackers and French defenders alike. But the true confusion was on board. Indeed, it was on May 9th over Arras, when a splinter faction of Futurists joined with the Cubists and forced a vote on whether to keep flying or land, that the Free Squadron's valiant career ended. The vote produced a deadlock, and after circling a landing field for hours, the Canard-et-Chicane ran out of fuel and crashed. It lives on today as a *frites* stand near a go-kart oval just outside Loos.



# Remembered



### **Amalgamated B-888 "Stratoflattener" Bomber, United States, 1953**

Only one prototype of this 14-engine turboprop behemoth (note accompanying B-17, dwarfed by comparison) was ever built. The Stratoflattener super-bomber never achieved its intended status; Senate hearings confirmed that the required crew contingent was too large to leave space for bombs and that training noise-deafened crew members to lip-read would drain the Air Force's budget. Mothballed in Arizona in 1954, the lone Stratoflattener gained a dubious new fame when it was started up at an Air Force Day celebration and triggered the Great Arizona Quake of 1959.



### **Bodo + Vulch BV-901 Night Interceptor, Germany, 1945**

No substantiation exists for the legend that Adolf Hitler himself designed the BV-901, nicknamed Hummer (Lobster). "He wasn't that batty," debunks one ex-Luftwaffe officer. It was in fact designed by the freshman class at the Hermann Göring Trade School for Boys at Karlsruhe in the waning days of the war. Power came from seven different engines, on the theory that if even one or two broke down or exploded, enough thrust would be left to keep the Hummer aloft. Turning the school's bus, furnace, refrigerator, and emergency generator into engines of one ingenious type or another, the lads did their best, but the Hummer's trajectory was naturally straight down, so the Luftwaffe recommended using it as a bomb. The Frau Goebbels Girls' Home Economics School was racing to design a plane large enough to carry it when the Nazi air war ended.



### **Hrabny-Chud "Mummo" Trainer, Czechoslovakia, 1945**

Secretly produced in a Prague tailoring plant during the Nazi occupation and powered by a single 56-cylinder engine made of 28 sewing machines, the Hrabny-Chud was slow and clumsy but "nert hobny de zignat adagnad!" (smooth as a sewing machine), according to those who flew her. Its unique modus operandi was: fly over retreating Nazi columns, stall, and make pancake landings on their hapless heads.



### **Naka R-2 "Marybeth" dive bomber, Japan, 1941**

The carrier-based Marybeth was one of the most feared of the Imperial Navy's single-engine torpedo bombers—feared especially by its pilot. So nose-heavy that it automatically went into a vertical dive the instant it left the deck, the R-2 had to be carried aloft by a mother aircraft and jettisoned directly over the target. Alas, since the Marybeth was unable to pull out of the ensuing dive and plunged straight down into the sea, every attack became a kamikaze mission. The aircraft was withdrawn from active service in 1942. Marybeths spent the rest of the Pacific war on the home front and saw limited duty. There are still Japanese who remember pilotless Marybeths screaming earthward to crash deep into the ground, doing their part by excavating new building foundations.



### **Plod 456 Whale Bomber, U.S.S.R., 1941**

The besieged Soviet Union faced starvation in the dark days of late 1941; one desperate hope was whale meat. The Plod was designed and built in six weeks to spot and harpoon the great beasts, and for the next 18 months Plods plied the Black Sea in search of prey. Then—scandal. It was found that no whales had ever existed in the Black Sea. The Plod's designer vanished. Teaching of marine biology was forbidden. Whale exhibits were removed from museums, and it was not until 1972 that the Black Sea reappeared on maps of the Soviet Union. The whale is depicted as a mythical beast in Russian classrooms even today, and the Plod was so utterly erased from the annals of Soviet aviation that a longstanding suit before the World Court at The Hague by Jane's *All the World's Aircraft*, intended to force the files open, was recently abandoned.



### **Spirit of Kim Il Sung 2R7-6 photo-reconnaissance aircraft, North Korea, 1968**

The 2R7-6's absence of windows marked an extreme expression of the notorious North Korean fetish for secrecy. The aircraft was designed to overfly many vital South Korean sites classified as top secret, but pilots could not be trusted to see such areas themselves. Thus a blind-flying pilot was forced to snap pictures by hoisting a hand-held camera up through an overhead hatch at the exact split-second he was ordered to do so by radio. Almost as bizarre as the 2R7-6's lack of fenestration was its "Sweet Breath of the Leader" steamjet engine, which regularly iced over at high altitudes and sent the craft hurtling earthward. This explains references in North Korean propaganda organs to "Dear Kim Il Sung's 'Let a Thousand Icicles Fall' Miracle."





### Stokely & Starkley "Unicorn" Fighter, Great Britain, 1939

Still noted for its role in the defense of Penzance—perhaps because Penzance never needed defending—the Unicorn was shifted in 1941 to the Middle East, where it was hoped that the unorthodox craft's frequent inexplicable prangs would distract Rommel's forces. The plan backfired after German propaganda boasted of all the ammo saved by not having to shoot down an aircraft entirely capable of destroying itself unaided. Splendid in intent and sincere in ambition, the Unicorn would play a vital role in the postwar world; the private papers of Lord Mountbatten reveal that it was Great Britain's gift to India of three squadrons of Stokely & Starkleys that clinched that nation's demand for independence.



### Bixby "Mysterioso," United States, 1940

This blurry snapshot is all that remains of the daring Bixby Mysterioso X-O prototype, still shrouded in rumor and controversy. The designer was Major Howdy Bixby, who continues to allege that his arrest as a Nazi saboteur shortly after this photo was taken reflected not fact but the American hysteria of the time. A special court-martial hearing seemed to support the major, who was judged not clever enough to be a saboteur or an aircraft designer.



# BIGFOOT



RUSSELL MUNSON

## How the rubber meets the runway.

by John Sotham

**I**t's the end of the flight, and the seat backs and tray tables have been returned to their full upright position. The main landing gear of the Boeing 777, its struts as tall as two-story buildings, unfolds from the wheel wells and swings down until the downlocks engage, which will prevent the sturdy titanium legs from collapsing during the landing, now only moments away.

The runway, stained with streaks of black rubber from the countless tires that have arrived here before these 12 Goodyears, rushes upward, and 500,000 pounds of aluminum, plastic, steel, fuel, passengers, and baggage slam onto the concrete. The main wheels, each 32 inches in diameter with 50-inch radial tires, accelerate from zero to 140 mph in less than a

tenth of a second. The tires bulge and shriek, parts of their tread surfaces heated to 500 degrees Fahrenheit. The telescoping struts are compressed several feet under the airplane's enormous weight, and the guy sleeping in seat 36F stirs but doesn't awaken, oblivious to the drama that has just played out below the cabin floor.

Of all the punishment an airplane experiences over its lifetime, landings are in a class by themselves: They are sheer torture on the tires and gear, and airplanes must endure them on every single flight. Engineers face some daunting challenges getting airplanes back down on the ground in one piece, and considering all that a landing gear is subjected to, it holds up admirably—largely because of careful design and testing.

One of the centers for such work is the Aircraft Landing Dynamics Facility at NASA's Langley Research Center in Hampton, Virginia. Here, a team of engineers tests the performance of gear struts, tires, and brake systems on military, commercial and research aircraft, including the space shuttle. ALDF engineers do much of their primary research with a 110,000-pound steel-tube carriage that carries landing gear down two steel rails to a "landing" on a short patch of runway. Propelled by a high-pressure water jet, the carriage, which looks like the kind of modern art sculpture you see in front of government buildings, is capable of reaching a speed of 250 mph and an acceleration of 20 Gs on its short trip down the track. Engineers can even douse the test surface with water to sim-



DON WARD/NASA LANGLEY



JOHN ROSSINO/LOCKHEED MARTIN

ulate a rain-slick runway. The carriage can capture 28 channels of data, such as cornering and friction loads from the tire or strut being tested, and the carriage itself is arrayed with hundreds of strain gauges that tell its operators if their apparatus is about to turn itself into a pile of water-propelled scrap metal. The researchers are primarily interested in the interrelated effects of different runway surfaces, landing conditions, and tire types.

Sometimes the focus isn't on the tire at all but on testing runway and taxiway surfaces themselves. In recent years, tests have been conducted on surfaces made from paver blocks, which can be used to make a taxiway that fits together like a tile floor and can be easily repaired. Another innovation, the grooved runway surface, which channels water away, was developed and tested at ALDF and is now in use worldwide.

Using the carriage, ALDF engineers have been able to predict tire wear under given steering stresses and crosswind loads. This work started in 1985 with tests to make sure the space shuttle could land safely. "With the shuttle, the speeds involved and the weight per tire are much higher

*The C-5's complex multi-wheel gear (top) was developed to satisfy an Air Force requirement to land on unpaved strips. NASA uses the carriage at left at its Langley, Virginia center to test landing gear and tires in conditions simulating actual speeds and loads.*



than any other airplane," says Bob Daugherty, an ALDF engineer. "And there are tremendous wear problems—especially during crosswind landings—to the extent that there was once a big concern about shuttle tires surviving even one landing." As a result of ALDF tests, the shuttle was given tires similar to those used on commercial aircraft and the surface of the Kennedy Space Center runway was altered to make it less abrasive. Both changes vastly increased tire life.

Another airplane that created headaches—but also taught important lessons—was the SR-71 Blackbird. "I'm being partly facetious, but my guess is that Kelly Johnson and his team at the Skunkworks put so much effort into getting the SR-71 from takeoff up to Mach 3 and then back again it was kind of like 'How do we get it to the hangar and from the hangar out to the end of the runway?'" says former Blackbird pilot Tom Alison, now a curator at the National Air and Space Museum. The SR-71's landing gear, which is small for a 100,000-pound airplane, was added "as if it was an afterthought," Alison says.

Because the SR-71's gear was perhaps its weakest system, Alison says that the mighty Blackbird had to be treated delicately on the ground. "You could lock the brakes up and skid the tires even at taxi speed if you stepped on the brakes real hard," he says. "You treated it like a large airplane on the ground, even though it had the performance of a fighter-type airplane."

These problems arise because designers of landing gear have always had to manage a host of sometimes conflicting requirements based on the mission and performance of the

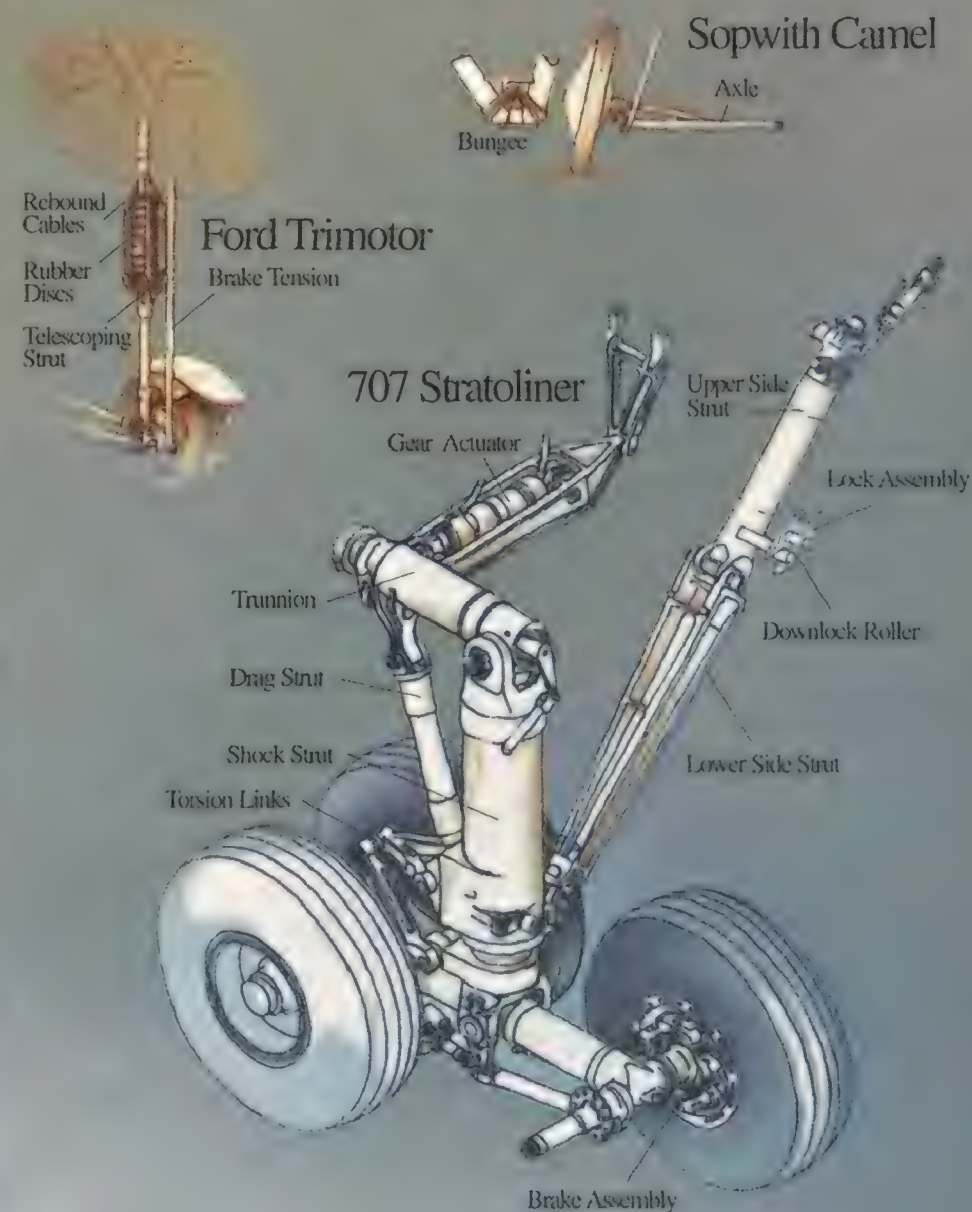
## Gearing Up

They started with simple skids. That's how the Wrights landed in the sand at Kitty Hawk. By World War I, landing gear had evolved into struts attached to the fuselage structure that could absorb impact and allow the aircraft to be maneuvered on the ground. The wheels were typically placed at the ends of a long single axle surrounded by layers of elastic bungee cords that absorbed the stresses of landing and takeoff.

Retractable gear was first tried as early as 1911, but it wasn't widely used until airplanes got bigger, resulting in a need to reduce airframe drag. The first fully retractable gear appeared in 1920 on the Dayton-Wright RB high-wing racing monoplane, in which the wheels folded into the fuselage. In 1922, the Verville-Sperry R3 racer was the first to retract its gear into its wings. Wood and fabric were replaced with the stressed-skin aluminum fuselage that endures today. As manual retracting gear gave way to hydraulic actuation, the associated equipment added complexity and weight, and gear grew heavier still because new, higher sink rates—how fast an airplane descends vertically before touchdown—had necessitated more robust construction.

By World War II, the elements of modern gear design were in place: compressible struts with multiple wheels, plus the tricycle configuration with its nosewheel, introduced on such aircraft as the Douglas DC-4 and replacing the tiny swiveling tailwheel that's still found on some light airplanes. The tricycle arrangement was essential for jets, the high landing speeds of which required the added stability conferred by the nosewheel. The airplane's center of gravity was now forward of its main gear and the groundloop was history.

Brakes were hydraulically actuated and built into the wheel hub. The first oil-dampened strut appeared in 1908, and was used on a British B.E.2 at the Farnborough factory in 1912, which led to their role today as essentially oversized shock absorbers filled with hydraulic fluid and compressed air or nitrogen to absorb impact. Oddly enough, the fastest winged vehicle ever piloted, the X-15, had a main gear based on—you guessed it—skids.



aircraft their gear will support. The U.S. Air Force, for example, wants the third largest airplane in the world, the C-5 Galaxy, to be able to operate from unpaved fields. The shuttle weighs as much as 240,000 pounds on landing, yet its gear must be capable of touching down either on a dry lakebed or on the Kennedy Space Center runway, which was once criss-crossed with tire-shredding half-inch-high channels that allowed maximum runoff during a typical Florida rainstorm. And the Navy and Marines like to slam high-performance fighters onto the decks of ships—punishment that would make non-seaworthy gear struts crumple like soup cans (see “Hitting the Deck,” p. 43).

“You’ve got a landing gear community out there that is a bit at the mercy of everybody else involved in aircraft design,” says Dave Morris, a senior project engineer at the Air Force’s Wright Laboratories at Wright-Patterson Air Force Base in Dayton, Ohio. The labs are a key site for gear and tire testing for all branches of the U.S. military, as well as for

*One little known role of the space shuttle is its contribution to gear design: Its undersized landing gear puts components to a severe test on every landing, thereby generating valuable—and extreme—data.*



manufacturers of commercial aircraft, tires, and gear. “They have to work with some constraints that are quite severe and that are not expected in other components in terms of weight,” Morris says. He points out that as aircraft evolve, they tend to get heavier, and problems often develop as their gear systems start to strain under the load. “The F-16 started out as a lightweight fighter around 25,000 pounds gross weight. Now they’re up to 48,000 pounds and the old tires couldn’t cut it anymore,” Morris says. After trying steadily higher tire pressures, the Air Force finally had to switch to a larger tire, which necessitated design changes in the lower fuselage in later production models.

Increased weight often drives advances in tire and gear design, and not only because of the need to support the airplane without failing under the load. Runway and taxiway

surfaces have their limits too, and will crumble under improperly designed gear. “Flotation” is the term describing the ability to spread the weight of an aircraft over a big enough area of ground to support it, and flotation is a direct function of gear and tire placement. Perhaps no aircraft offers a better example of this principle than the monstrous Convair B-36 Peacemaker, a bomber designed during World War II to attack targets halfway around the world from bases in the continental United States (see “B-36: Bomber at the Crossroads,” Apr./May 1996).

The pre-production XB-36 had main landing gear struts equipped with a single wheel and tire nearly eight and half feet high. “The footprint area was so small in that big wheel, it concentrated too much of the load,” says Max W. Schelper, a former Convair engineer who worked on the B-36. Only three airfields in the United States had the specially built, 24-inch-thick, steel-reinforced concrete runways the XB-36 would have required. “The crying need was to go to a bogey-type [multiple-wheel] gear to spread the footprint out and to allow it to land on any of the heavy-duty runways then in existence,” Schelper says.

At one point, the engineers tried to do away with tires altogether and outfit the XB-36 with a tracked system, which made the huge bomber look like it was being carried by two Sherman tanks. Not surprisingly, the large tracks weighed 5,600 pounds more than the improved multiple-wheel gear. “I won’t call it a disaster, because the XB-36 [with the experimental tracks fitted] was the only aircraft that could operate out of Wright-Patterson Air Force Base in snowstorms,” Schelper says.

Other aircraft also got the track treatment. Experiments were conducted with such aircraft as a Fairchild C-82 Packet and a Douglas A-20, which was even able to traverse mud

and sand. In all these installations, extra weight was almost always the downfall, along with the difficulty of keeping a very complex system of rubber-covered tracks operating at the high speeds encountered during landing and takeoff. In the case of the track-equipped XB-36, “every time you hit the runway, rubber would fly off,” Schelper says.

Lesson learned: For better flotation, add more tires of reasonable size. The Air Force



SCOTT ANDREWS (4)



BEN ROSS

*Convair's "B-36 Freighter," the XC-99, shared the early bomber's huge single-tire main gear, which tore up runways and gave way to four-wheel mains (right), offering better flotation and easier stowage.*

got its wish on the gigantic C-5 Galaxy, which was at one time the largest airplane in the world. The airplane can (in theory but very rarely in practice) operate on bare soil, thanks to its 28 tires, arranged on four six-wheel struts and a four-wheel nose strut. The problem with all those struts and tires, though, is that they add so much weight. It's tough to provide adequate flotation without incurring a whopping penalty.

The answer for the Boeing 747, still the largest commercial passenger jet today, was to use four main gear struts to support its bulk, which can exceed 700,000 pounds. Other wide-body airliners have used a similar approach, such as the DC-10-30 and the Airbus 340, which have vestigial-looking two-wheel gear struts mounted between their twin four-wheel mains.

When Boeing landing gear designers turned their attention to the new 777, they faced a familiar problem: A big, heavy airplane needs a lot of flotation, but additional landing gear struts add a lot of weight and space is limited. The solution was two six-wheel struts, the largest ever attached



to a commercial aircraft. Each 50-inch-diameter tire measures 20 inches across. The six-wheel arrangement prevented the need to add additional struts, and by using titanium extensively, Boeing kept the weight down even further.

The 777's designers also faced the perennial problem of where to put the gear when it retracts into the wheel wells. "You're always strapped for space, because they want to put freight, electrical bays, air conditioning packs, and goodness knows what else down there," says John Davies, a Boeing landing gear designer. "I can remember times when [airframe designers] have configured an aircraft, figured out where they want a gear, but not where to stow it. Sometimes you start working on that process later than you might want. But I think that's turning around with the advent of computer-aided design systems. More people realize the importance—the airplane spends a lot of time on its gear." Today, gear designers are more involved from the beginning of the design process, Davies says.

The actual manufacture of landing gear is sub-contracted to



NASM



FAIRCHILD AIRCRAFT



VIA AIR FORCE MAGAZINE

*In 1948, this Fairchild EC-82A took off on experimental Firestone tracked gear. Count Giovanni Bonmartini had a similar idea for Piper Cubs and other light airplanes (top, left). Billed as the "built-in runway," tracked gear was aimed at reducing ground pressure. It never caught on, and production C-82s used traditional tires (top, right).*

a handful of companies that specialize in building struts, such as Menasco and BFGoodrich Aerospace. Sometimes, gear engineers from contractors are actually detailed to a particular aircraft manufacturer so they can design the gear in-house. Once the design is finalized, the contractor takes over manufacture of the components, says Louis Hrusch, chief engineer for BFGoodrich's landing gear division. Gear legs are made by forging, which offers good strength-to-weight ratios and involves taking a rough cast of the

part and essentially compressing the material, usually steel alloy or titanium, into shape. "Forging gives you better properties all the way around, in terms of fatigue and wear. You start with a cast ingot and heat it to a semi-solid and you pound it in that state," Hrusch says. In terms of materials, steel is still the best material for building landing gear since

it is stronger than titanium, although titanium wears better and is much less prone to corrosion, he says. After the strut is forged, wheels and brakes are then attached after being designed and built by subcontractors to exacting specifications provided by the aircraft manufacturer. Designing and building brakes and wheels demands "pretty unique expertise," says Davies. That's because in any gear system, the wheels, tires, and brakes take the brunt of the effects of high speeds and the violence associated with even routine taxiing, takeoffs, and landings.

The appearance of a telltale puff of blue smoke that marks the contact of the tire on the runway is not necessarily when most of the wear on aircraft tires occurs, despite the streaks of rubber deposited on those blackened touchdown zones. Tire wear is a complex problem that depends far more heavily on whether the tire is aligned with the direction of the airplane's motion. "If there is a crosswind, you're never really rolling straight down the runway even if your body is going straight," Daugherty says. "You're actually cocked into the wind, and that really tears up tires." An airplane's tire under a crosswind literally gets bent out of shape. The part of the tire that isn't in contact with the runway or taxiway is constantly being pulled sideways as the tire distorts under the load. The combination of crosswinds on rollout and the steering forces exerted during taxiing causes tremendous wear, accounting for 90 to 95 percent of the total.

Designers of the Boeing 747 gear discovered early that making the inboard main gear wheels steerable helps relieve the strain imposed on the gear system. That steerable system was not installed on the first 747, but was added soon after the inboard main tires experienced high wear from scrubbing laterally across taxiways and runways as the aircraft turned. The newer 777's gear has a similar feature: The aft two wheels of each main gear are steerable. On airliners with two or four wheels on two mains, only the nose wheels are steerable since side forces are less of a problem.

Wheels and tires also get pretty hot, primarily as a result of braking. Most modern aircraft brakes are enclosed within the wheels of the main landing gear and comprise an alternating stack of smooth metal rotors and stators, which are bonded to friction-producing pads made from metal or carbon compounds. When the pilot pushes on the tops of the rudder pedals to activate the brakes, the whole stack of plates is squeezed together by hydraulic cylinders arranged around the wheel. All that friction, especially at high landing speeds, produces tremendous heat that radiates directly into the tires, which are inflated with nitrogen or air to a pressure of several hundred pounds

BF GOODRICH CO.



ERIC SCHULZINGER/LOCKHEED MARTIN



*The North American XB-70's airframe got so hot at supersonic speeds that its tires required a reflective coating and had to be tested at temperatures hot enough to boil water (left). A similar silvery coating was applied to the Lockheed SR-71's tires (above), which get even hotter.*

per square inch. The combination of pressure and heat is sometimes explosive: The air inside the tire gets hot enough to blow apart either the tire or, sometimes, the entire wheel assembly. Even though it dissipates pretty quickly, a quick burst of heat is also produced by the violent contact of tire and runway. "If they have a shuttle landing at night, they'll use an infrared camera," Daugherty says. "When you look at the tires in infrared, they just turn on like lights."

In aircraft that spend a lot of time at extreme speeds and

*A Boeing 737 can expect to get about 200 landings on a set of rubber. Bottom: This Convair 990 got only one when a 1995 test of the space shuttle's landing gear exceeded the tires' limits and started a spectacular fire.*



CHAD SLATTERY

Alison says that each of the Blackbird's tires are pressurized with 400 pounds of nitrogen, and at touchdown speeds of around 180 mph, it wasn't uncommon for a pilot to blow a tire when braking because of the tremendous buildup of heat. "You could hear the pop clear up in the cockpit," he says. Pilots and ground crews were cautious around the tires until they had cooled off a bit. Immediately after every shutdown, SR-71 crew chiefs set up large fans to blow cool air over the hot tires and brakes. "You could see the wheels smoking, and that was when you had been doing everything right," Alison says.

The individual components are important, but a landing gear design can succeed only if the wheels, tires, struts, and brakes work in harmony. The wrong combination can spell disaster, which is exactly what happened during tests of experimental electrical brakes tested on a Republic A-10 Thunderbolt. When the new brakes were installed on a strut, the action of the brakes induced a "gear walk," a rapid fore-and-aft movement that snapped the strut completely off the test airplane.

The need to eliminate adverse movement and vibration in a landing gear system becomes increasingly important as aircraft age. "After 10 or 20 years, the various joints and pieces get a few thousandths of [an inch of] wear here and there, and pretty soon you've got a system where things are shimmying," Daugherty says. "And in fact, there are gear



TIM MILLER VIDEO/NASA

altitudes, aerodynamic friction on the skin creates another type of problem involving heat. SR-71 Blackbird tires have always sported a flashy silver coating to reflect the heat radiated by the hot skin just inches away. "Almost everything on that airplane was designed with heat in mind," Tom Alison says. "People ask me how fast would it go, or what the limiting airspeed was. There wasn't a limiting airspeed, but there was a limiting temperature, and your speed was determined by how hot it got."

snapping off out there in the commercial world too."

In response, ALDF engineers are developing devices that can monitor the health of a landing gear system and detect minute vibrations and movements that could cause significant problems later on. The data can be stored and downloaded later at certain intervals in an airplane's service life to help predict patterns of potential failure.

Sometimes gear problems appear before the airplane is even built, as is the case with the High Speed Civil Trans-



*The X-15 had skids for main gear and slammed down on its nosewheels at every landing. Once when it was overweight and had to make an emergency landing, its fuselage broke in two.*

VIA AIR FORCE MAGAZINE

port, a supersonic aircraft envisioned to cut transoceanic travel times dramatically in the 21st century. The airplane's unique size and shape make it a prime candidate for problems, even when taxiing. The HSCT features a long, slender forward fuselage, with a nose gear located farther back than it is on current airliners. That arrangement can create a situation whereby the up-and-down motion of the nosewheel,

The taxiways at Edwards Air Force Base in California, with seams about 20 feet apart, played the airframe as if it were a guitar string. The frequency of the potential vibration present in the forward fuselage corresponded exactly to the spacing of the seams at certain taxi speeds. "It was about two cycles per second and it worked out that at about 20 miles per hour, every time you hit one of them it was am-



CHECK SIX

### **Hitting the Deck**

"Definitely, the carrier landing is way out there in terms of severity," says Wright Laboratories' Dave Morris, whose facility at Wright-Patterson Air Force Base tests Air Force as well as Navy gear systems and components. In carrier suitability trials, the Navy tests its aircraft to the limit to make sure the gear and airframe can hack it. Morris says, "They test them all the way out to the ultimate case where you're coming in to land on a carrier, you've dropped your hook, you're at maximum height above the deck and you feel you've missed the cables, so you go to full afterburner. But in fact, you've engaged the hook with the aircraft at maximum height. I've seen the video of the tests on the F/A-18, and it's a test you only want to do once, because the airplane starts to rotate

in space once the hook is engaged, and turns nose down and basically flies into the deck at full throttle. Some pilot drew the short straw and had to fly that profile, verifying that worse-case condition."

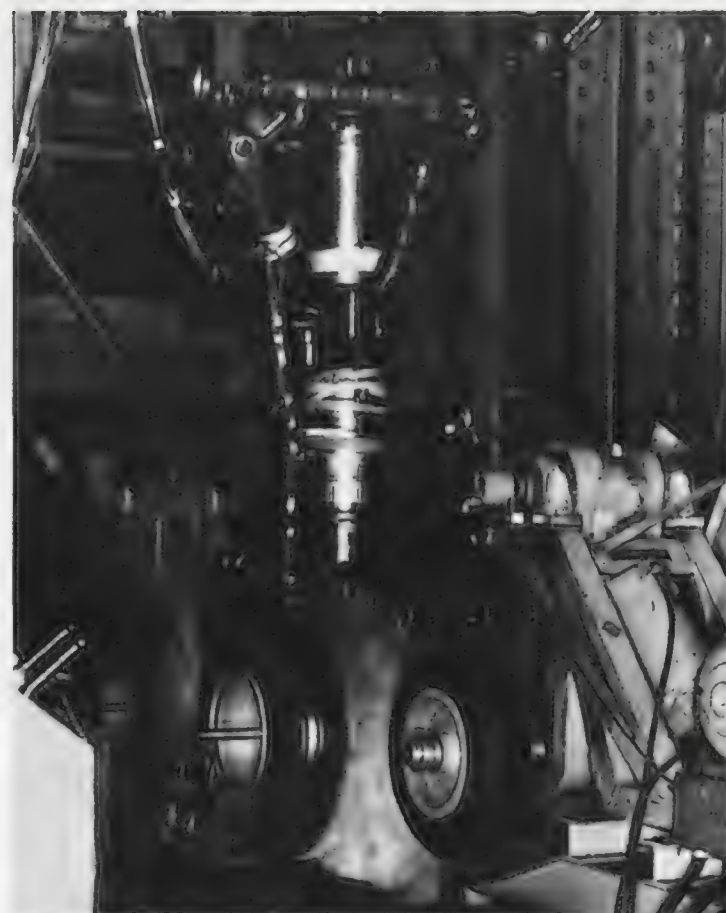
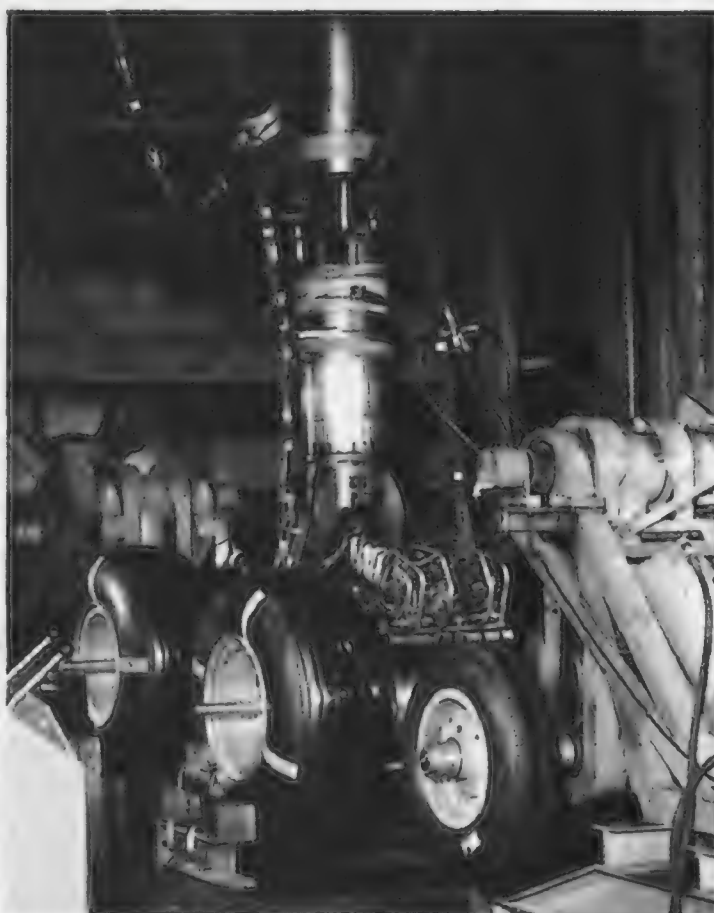
The landing gear can account for more than 25 percent of the weight of a U.S. Navy aircraft. "It's not just the gear installation itself, it's all the supporting structure too," says Tim Wooldridge, a former naval aviator and now a curator at the National Air and Space Museum. Wooldridge was present for the introduction of the McDonnell F-4 Phantom into the fleet in 1961. Early Phantoms frequently blew tires on carrier landings, so the logical answer seemed to be more pressure. Wooldridge recalls watching a tire being deliberately inflated to 500 pounds, more than 100 pounds over the recommended pressure. Had the tire blown, it would have taken the wing of the airplane with it, Wooldridge says.

The requirements of naval aircraft have also driven advancements in the materials used to fabricate landing gear. New materials, like titanium matrix composite, which is made from ceramic fibers embedded in titanium, combine superior toughness with light weight. The titanium is very strong, but it's also brittle, so the ceramic matrix allows the material to bend. Another benefit of composites is that they are very corrosion-resistant—you don't have to paint them. Cracks, damage, and any flaws produced by the manufacturing process will therefore be more apparent, making inspection easier. Right now, most of the problems lie in developing manufacturing techniques to take full advantage of the new materials. Titanium matrix is the first truly new material for landing gear to be developed in the last 30 years of aircraft design, Morris says. Today, most gear parts are made from various types of steel alloy, titanium, or even aluminum.

plified. If you sped up or slowed down a little bit, it stopped right away."

The answer for the HSCT may lie in building a smarter gear. Researchers at NASA's Langley Research Center are working on an active control system that could dampen the motion by quickly redirecting the hydraulic fluid in a strut in response to vibrations caused by taxiways and runways. The system may employ sensors placed in the nose of an aircraft that can detect irregularities in the pavement ahead and then send that information to a control system that will direct the strut to respond accordingly to dampen the shock. Tests of the system are being conducted using an old A-6 Intruder strut at-

NORTH AMERICAN AVIATION (2)



*Tests of the XB-70's main gear (above) at Wright-Patterson Air Force Base simulated an aborted takeoff at maximum gross weight. After contact (right), the brakes withstood stresses 20 percent over their design limit. On one test flight, the big bomber (below) suffered a severe landing gear fire that blew all the main gear tires.*

tached to a hydraulic shaker table, and results have been promising. The new technology could also be applied to other aircraft, such as tactical airlifters, which sometimes operate from unconventional surfaces.

In the small world of landing gear design, engineers are working on new materials, active control struts, and computer monitoring systems. No matter what future aircraft look like, those unsung legs with all the wheels hanging off them will be there, tucked into wings or fuselages, doing their job with heat, smoke, and noise but little fanfare. —

U.S.A.F.



# ***BOMBERVILLE***

**It could be your town if these guys land there.**

by Lance Thompson

*Photographs by Michael Melford*



*Relics of World War II, a restored B-24J Liberator (foreground) and a B-17G Flying Fortress are bringing their vintage charm to admirers in more than 100 U.S. cities.*

In a chilly New England drizzle, they press against a chain link fence, scanning the skies. There's a curious cab driver on his day off, a sweater-clad four-year-old perched on her father's shoulders, and a computer programmer shivering despite the embrace of a boyfriend in a surplus flight jacket. And there are many old men wearing ballcaps and windbreakers, which are adorned with embroidered patches and enameled pins that depict the aircraft their lives once depended upon—Boeing B-17 Flying Fortresses and Consolidated B-24 Liberators.

Their patience is soon rewarded by the sight of two incoming bombers: *Nine-O-Nine*, one of a handful of B-17s still flying, and *All American*, a fully restored B-24J. Together the two warbirds make up a self-contained airshow that will stop in 137 towns in 35 states. The 10-month, coast-to-coast tour has been organized by the Collings Foundation of Stow, Massachusetts, a non-profit group that has been flying the World War II-era aircraft since 1987.

Founder Bob Collings originally envisioned the B-24 as a static exhibit, but friend and B-24 veteran Don Sparks observed, "If you do that, two or three

Powered by 1,200-horsepower piston engines (right), the bombers announce their arrival with an unmistakable roar.



thousand people will see it a year. If you fly it around the country, two or three million could see it." Both bombers required extensive and costly restoration. "People told me they would never fly, and if they did, it wouldn't be economically feasible to keep them flying," says Collings. "Fortunately, I wasn't smart enough to know that." A retail computer systems entrepreneur, Collings feels that bringing these old airplanes back to life is one way to show his appreciation to World War II veterans. "We can never pay them back," he says, "but if people can get inside these planes, see them fly, and fly in them, they'll get some idea of what these men went through."

The Allies flew thousands of B-17s and B-24s—perhaps most famously in daylight bombing raids over Germany—and though losses were high, many crew members survived the war because the aircraft were built to take punishment. Assigned to every theater of the war, the B-17 in particular was known for withstanding battle damage and safely returning its six- to 10-man crews. The B-17G flown by the Collings Foundation (serial no. 44-83575) was manufactured late in the war and never served in combat, though it did fly as part of the Military Air Transport Service before beginning a 20-year stint as a fire bomber. But the B-17 it was named after, the original *Nine-O-Nine*, was deployed on February 25, 1944, and flew 140 missions without an abort or loss of crew before being scrapped.

The foundation's B-24 (serial no. 44-44052) flew in the Pacific theater from October 1944 until the war ended. The bomber was named *All American* after a B-24 that was part of the 15th Air Force's 461st Bomb Group. On July



25, 1944, the original *All American* shot down 14 enemy fighters; two months later the aircraft was lost over Yugoslavia, though all of the crew survived.

The foundation's B-24 is still flying thanks to a \$1.3 million restoration that required nearly 100,000 hours of work, much of it volunteer. The old bomber had to have over one-third of its aluminum skin replaced, as well as 5,000 feet of hydraulic lines, a mile of control cable, and all of the electrical wiring. The foundation is still paying off loans it took out for the restoration; much of the expense is offset by private donations. (The aircraft earn enough money on tour—through souvenir sales and contributions from visitors—to cover the cost of maintaining them.)

Organizers set the route and schedule typically four to six weeks ahead of the airplanes, relying on local coordinators to organize publicity, secure ramp space at the airport, and arrange for crew lodging and

transportation. Coordinating the tour in transit is the job of Phil Haskell, the operations and supply officer of the two-plane air force. A 61-year-old ex-Army aviation crew chief, Haskell became involved in 1986, when he volunteered to help restore the B-24. He is the team's answer man. Whatever the question—How many hours on the number-three engine? What's the price of fuel in Burbank? What state will we be in a week from Tuesday?—Haskell can pull out a spiral notebook from his nylon flight jacket and find the answer.

He also schedules the rides, a responsibility complicated by cancellations due to weather, unexpected maintenance requirements, and last-minute no-shows by riders. With operating costs for each bomber averaging \$2,000 an hour, the foundation requires a minimum of six people paying \$300 each for a 45-minute ride. "We're not an airline," explains Haskell. "If we only have five, we don't go."

*The expense of taking the airplanes on a 10-month tour is partially offset by such sponsors as Schlitz, whose Golden Girl looks right at home on All American's nose.*

Those who do get to go are rarely disappointed. Ken Virchow, 48, of Bolton, Connecticut, savored every sensation of his ride on *Nine-O-Nine* from the moment the Wright-Cyclone R-1820-97 engines kicked over and coughed out a charcoal gray cloud. "Exhaust smoke seeps up through the bomb bay and ball turret opening," says Virchow. "There's lots of vibration as they run the engines up, but once those propellers bite the air and you start to move, it's tremendous." Robert Hardy of Worcester, Massachusetts, who flew 71 missions in B-24s for the 456th Bomb Group, enjoyed a 75th birthday ride on *All American* courtesy of his grandson. "Haven't been on one since 1945," Hardy shouts over one of the still-running engines. "It was fantastic!"





Two full-time mechanics, Mike Nightingale and Bill Strawn, keep the bombers running. Nightingale, 28, is a wiry Californian who grew up restoring P-51 Mustangs. His toolbox looks like one that could be found in any home garage. "Usually we can borrow anything else we need from somebody at the airport," he explains. When a rainstorm in Hartford, Connecticut, cancels all flights and drives everyone else indoors, Nightingale is up on a ladder, shoulder-deep in the B-17's number-two engine, trying to locate a malfunctioning cylinder. "This is a chance to do real field maintenance," he rhapsodizes. "To be able to work on these airplanes and fly in them—that's absolutely fabulous."

Strawn, 42, was a Chevrolet mechanic in Florida before getting his airframe-and-powerplant license and joining the tour. When he volunteered to help replace an engine on *All American* during a stop at Clearwater, Florida, he was hooked. Of the foundation's two bombers, Strawn believes the B-24 is the greater maintenance challenge. "Every engine has two banks of seven cylinders and there's more cowling to take off," he says. He points at the engines, nine feet above the runway. "You get up on a ladder on a windy day, you'll know why this one's tougher," he continues. "You sure get attached to it, though." With a new B-24 tattoo on his upper back, Strawn is now a dyed-in-the-skin Liberator man.

*Team mechanics thoroughly inspect the aircraft after every 50 hours of flight. A \$1.3 million restoration put All American (above and below) back on flying status. Restorers rebuilt the radios, armament, and glass turrets and installed new tires, fuel cells, and a Norden bombsight.*

Sticking to the tour's schedule is a high priority, but safety comes first. Though both airplanes get thorough overhauls during an eight-week winter hiatus in Florida, while on tour they are inspected after every 25 to 50 hours of flight. When an unexpected repair grounds one bomber, the other keeps the schedule. "If we need something big, like a new engine, the foundation ships one out," explains Haskell. (Foundation members hunt continually for spare parts, scavenging from parts distributors, private collectors, and junkyards.)

Keeping *Nine-O-Nine* and *All American* airworthy is a full-time job, but only part of what it takes to keep the tour on track. A diverse group of volunteers travels with the aircraft, taking donations, loading and unloading gear, organizing riders, assisting the mechanics, and manning the souvenir tables (referred to by the team as "the PX"). Dee Brush, 31, is a plainspoken native of Boca Raton, Florida, who might have inspired some engaging nose art in the heyday of the bombers. When a carpal tunnel condition ended her career as a court stenographer, she left her hometown—for the first time—aboard a vintage bomber. "I'm single," she says. "I've got no kids. This is the opportunity of a lifetime. My friends think I'm the luckiest girl in the world."

Richard Ziel, 19, has been with the tour for seven weeks. His parents called the foundation, explained their son's fascination with warbirds, and arranged for him to join the tour as a high school graduation surprise. "Most of my friends don't even know what these planes are," he says.

The bombers are flown by a team of pilots on vacation from day jobs. Jim Sheehan, 35, a DC-10 and MD-11 pilot for American Airlines, once flew DC-3s, DC-4s, and

Constellation freighters in the Dominican Republic. "I could fly 'em and I could fix 'em when they broke in the jungle," says Sheehan, who calls the B-17 "the most pleasurable airplane I've ever flown."

"I'm used to flying at 35,000 feet from ugly airport A to ugly airport B," he continues.

"Here, you're down low enough to enjoy the scenery. Flying down the Columbia River



gorge and looking *up* at waterfalls, you feel real lucky." There's another sensation Sheehan doesn't get in the jumbo jets. "In the MD-11, you're in a pressurized cabin," he says. "Here you can slide open the window and smell that 60-weight oil burning off the engine. That's yummy."

Bob Lowenthal, 59, a 747-400 captain for Northwest, has just joined the tour. "Ever since I was a boy I've been reading about B-17s," he says. "When I first started flying with the airline, all the captains were World War II bomber pilots." One of the pilots Lowenthal is now learning from is Rob Collings, Bob Collings' 23-year-old son and an experienced warbird pilot.



*Going on tour with old airplanes leaves little time for recreation, unless you count the hours spent soaring across the countryside in a B-17 (above).*

"When I first got here," remembers Lowenthal, "I thought, *Who's this cocky kid showing me how to fly?* Then I thought, back in 1943, that's exactly who would be sitting in the left seat—a 23-year-old hotshot."

Some 50 years ago, that's exactly what tour member Dick Dinning was. A tall, lean, soft-spoken veteran of the 351st Bomb Group, Dinning flew 33 missions as a B-17 pilot. He has a warm smile, a sympathetic ear, and the deep respect of everyone on the team. Even mechanic Strawn, whose merciless impressions of crew members spare almost no one, addresses the veteran pilot as "Mr. Dinning." Dinning flies chase in his single-engine Mooney 252, ferrying pilots and spare parts and using a Stormscope lightning detector to lead *Nine-O-Nine* and *All American* around rough weather.

When the three airplanes land at a stop, everybody pitches in, including the pilots. Folding tables have to be unloaded, along with chairs, crew luggage, tools, spare parts,

canopy covers, souvenir T-shirts, coffee mugs, books, videos, photographs, patches, and inert .50-caliber ammunition (a big seller). Ladders have to be lowered, and signs displayed to guide visitors through the aircraft. Fuel and oil levels are checked, oil wiped off of engine cowlings and wings, and Plexiglas windshields cleaned with Lemon Pledge. Yet the first visitor steps aboard less than 15 minutes after the propellers stop turning. "These people have been waiting a long time," explains Haskell, waving his arm at the assembled crowd. "We have to move fast or we lose them."

With riders scheduled from first light to dusk and a constant stream of visitors, there are few idle moments. The team set a record of 21 local flights during a



1996 stop in Fort Collins, Colorado. "After a day like that, you shut down, get supper, go back to the hotel, and do a spin into the mattress," says Sheehan. "Then get up at six the next morning and do it all over again."

Team members usually salute the end of the day with a cold beer, then follow their own preferences. If there is mechanical work to do and the ramp is equipped with lights, Nightingale and Strawn go back to work after dinner. Phil Haskell spends evening hours on the phone, scheduling riders for the next day's flights. As for the others, "some go dancing, some to movies, some just crash," says Dee Brush.

Ask anyone on the team what makes the rigors of the road worthwhile and you'll get the same answer: the veterans. Michael Garemko of Hartford, Connecticut, a top turret gunner from the 100th Bomb Group, approaches the B-17 tentatively. "Just let me touch it," he whispers, running his fingers across the underside of the wing. Robert Bogue of Norwich, Connecticut, an ordnance handler for the 392nd Bomb Group, listens to the B-24's 1,200-horsepower Pratt & Whitney R-1830-65 radials throttling up. "Oh, what a sound!" he exclaims. "You can't put a dime on me right now without hitting a goose pimple."

Some come to stare in silence, taking the trip back in time alone. Others come with

*Scrapbooks appear at almost every stop the Collings team makes (above), brought by veterans who revive their wartime memories in the shadow of a vintage bomber.*



comrades to reminisce. Often *Nine-O-Nine* and *All American* bring together men who haven't seen each other since the war, as well as strangers who discover they were in the same outfit and greet each other like long-lost friends. There are tears and smiles, and many, many photographs. From meticulously arranged scrapbooks, well-worn leather billfolds, and tissue-soft envelopes come surprisingly sharp black-and-white snapshots of young men in uniform, standing proudly in front of the mightiest warplanes of the day.

If there's a time and place veterans will talk about their experiences, it's in the presence of these airplanes. Bob Collings can't forget one tour stop when a young boy, his father, and grandfather, a wartime B-17 pilot, showed up for a visit. "The grandfather had suffered a stroke eight years before," remembers Collings. "He was still sharp and alert, but his speech was completely garbled." Yet when the veteran pilot got up to the cockpit and began to tell his son and grandson about his experiences, "all of a sudden he was very articulate, describing flak hitting the cockpit, the airplane on fire, bailing out with his crew," says Collings. "It was the first time his grandson had ever heard him speak clearly, and he told them the whole story."

As the crew members load their gear and prepare for takeoff, their visit suddenly feels all too brief, but there's another crowd at the next airfield, and the team doesn't want to keep them waiting. The bombers climb into the sky, leaving behind two kinds of people: those who wish they could go along, and those who've already been there.

*For more information about the bombers and the 1998 tour, visit the Collings Foundation Web site at [www.cyberhighway.net/~cessna](http://www.cyberhighway.net/~cessna) or call (508) 568-8924. ✈*



# Southern Africa

Visit South Africa, Zimbabwe,  
Botswana, and Namibia

August 31 to September 14, 1998

Southern Africa encompasses thousands of miles of rugged savannah woodland, open grasslands, great river systems and expansive deserts. Flying aboard a classic DC3 aircraft, enjoy the majesty of Africa on this unique, unforgettable adventure.

Highlights include the mile-wide Victoria Falls, the Okavango Delta, the ancient lake of Etosha Pan, the expansive and rugged Skeleton Coastline, the Namib desert, where red sand dunes stand over 1000 feet high, and finally, the floral kingdom and coastline of Cape Town (on an optional 3-day extension).

For the aircraft enthusiast, a special treat is a behind-the-scenes tour of one of the most unusual historic aircraft collections in the world, which houses a fleet of fully-operational DC3's, DC4's, and a JU52.

We hope you will join Smithsonian's own Dr. Michael Robinson, Director of the National Zoo and an airplane enthusiast, for this exciting, classic flying journey.



SMITHSONIAN  
STUDY TOURS

*by air*



*Aboard a private, DC3 aircraft*



Call Smithsonian Study Tours at (202) 357-4700 for more information!

Visit us on the web at [www.si.edu/tsa/sst](http://www.si.edu/tsa/sst)

CODE: AS

# ROCKETS FOR THE REST OF US

*Plenty of people complain about the high cost of reaching orbit, but a few brash newcomers—and some old NASA hands—are doing something about it.*

by Charles Petit

*Photographs by Phil Schofield*

The cargo first appeared out of the darkness as a distant, wide-set pair of green and red navigation lights, low in the northern sky. Waiting on the flight line of what used to be Mather Air Force Base near Sacramento, California, on this August night were 13 flatbed semi-trailer trucks, their drivers milling about, making small talk. Weeds grew through cracks in the concrete where Strategic Air Command crews once parked their B-52 bombers. A small crowd stirred excitedly.

The dark shape between the lights materialized into an Antonov An-124, the world's largest commercial freighter aircraft, designed for the once-mighty Soviet Air Force. It lumbered, fat and low like a walrus with wings, across the concrete and eased to a stop in a pool of illumination from a rickety set of

portable lights. Customs agents checked papers aboard the airplane, operated by an Anglo-Russian outfit called HeavyLift-Volga Dnepr. Slowly, the large doors under the tail opened.

Lined up like big lumpy sausages wrapped in brown paper and translucent plastic were the crown jewels of the ill-fated, once-secret Soviet moon program: 25 rugged, restartable NK-33 rocket engines and nine NK-43s, built to power the colossal N-1 launcher. The Soviets gave up their lunar landing plans in 1974 after the N-1 failed in four launch tests. But intoxicated by the engines' power, their builders managed to save them. They went, nearly forgotten, into storage at a Soviet design bureau in Samara, Russia. Now the engines have been sold for a song to the Americans they were meant to defeat.

One of their new owners, in fact, is George Mueller, who at 79 is one of the grand old men of the U.S. space program. Mueller was NASA's head of manned spaceflight in the Apollo era and has been called the father of the space shuttle. Today he is president of Kistler Aerospace Corporation of Kirkland, Washington, near Seattle. Back during Apollo, he heard rumors that the Soviets were trying for the moon too. But he'd never heard, until much later, of the N-1 or these magnificent engines. Now he is staking his company's future on them.

Kistler hopes to use the Russian rocket engines as the powerplant of a new, low-cost launch vehicle called the K (for Kistler)-1. If the company's marketing projections are right, the K-1 should have plenty of business in the next



*Apollo veteran George Mueller came out of retirement to join in the new space race, this time for profit. His secret weapon: cheap restartable engines (below), built for a Soviet moon rocket that never flew.*

decade delivering small- to medium-size satellites to orbit. But the key to success will be keeping costs low—hence the importance of hardy, reusable engines purchased at a bargain price.

Kistler isn't the only company out to change the economics of space transportation. At least a half-dozen new, privately funded, and best of all cheap rockets are coming soon—perhaps—to a spaceport near you. The concepts include a spaceplane that would be refueled by a tanker in flight and one that would be towed like a glider before rocketing off into orbit. Another would leap into space like a helicopter, rotors spitting flame. Most will be reusable, in whole or in part. Some are so secret their designers hardly talk about them, except to boast that they'll beat the pants off all comers, from oldtimers to upstarts. Some will carry people—crews and eventually passengers—and some are to start flying (or at least crashing) this year. By next year the first of the new launch systems may be in com-

mercial operation. Their goal: to haul small satellites into orbit for a fraction of today's prices.

To some, the ferment is reminiscent of the aircraft industry in the 1920s and '30s. "This is the new age of barnstormers," says Air Force Lieutenant Colonel Jess Sponable of the Phillips Laboratory in New Mexico. Sponable spends a lot of time with companies proposing new ways to deliver Air Force pilots or cargoes to orbit, or visit satel-



COURTESY AEROSPACE CORPORATION

lites surreptitiously, or get from one side of the world to the other in a hurry.

"Most of these companies will die," he says. "But some will survive. What's different now is that the technology is really there. Not only in NASA but in industry. And not just the big companies have the know-how. So do these little startups."

We've heard promises of cheap rides to orbit before. Ten years ago the same kinds of claims were made for AMROC's Industrial Launch Vehicle, EER Systems' Conestoga, and

the Liberty vehicle designed by Pacific American Launch Systems (see "The California Rocket Race," Dec. 1987/Jan. 1988). Not one of them is flying today.

But, say the current crop of hopefuls, the market has changed dramatically. More than 100 satellites are due to be launched each year for at least the next decade, according to some projections. Most are headed for low- to medium-Earth orbits. A \$3.4 billion Motorola-backed system called Iridium, with 66 satellites each weighing 1,500 pounds, already is being deployed (several at a time on larger, conventional rockets) to provide wireless phone connections worldwide. A second Motorola constellation called Celestri, with enough capacity to handle Internet traffic or other serious data transfer, will have 63 satellites. A partnership led by Loral and Qualcomm plans a \$2.6 billion, 48-satellite constellation called Global-Star. The biggest of the planned ventures, called Teledesic and backed by Microsoft founder Bill Gates and cell phone tycoon Craig McCaw, will spend \$9 billion putting up a whopping 288 satellites, plus a couple dozen spares.

Although established launchers like Boeing's Delta 2, Russia's Proton, and the Chinese Long March have already claimed much of this business, the newcomers hope to find a niche carrying



*Kistler's management is a Who's Who of aerospace: (above, from left) former NASA space station chief Dick Kohrs; ex-Rockwell engineer Joe Cuzzupoli; Dale Myers, former deputy head of NASA; and Dan Brandenstein (right), who flew four times on the shuttle.*

replacement spacecraft to orbit. Upgrading large networks like Iridium may provide steady business for years. But that market is by no means certain, which is why investors haven't exactly been pumping capital into the new ventures. With development costs for little rockets ranging from \$100 million on up, the new rocketeers are confronted with the same problem "faced by the Wright brothers and countless other pioneers of new technologies," says Chad Madden, a business development manager with Motorola's Satellite Communications Group: fear of the unknown.

Kistler Aerospace hopes that seasoned managers and sturdy, proven Russian rocket engines will help it beat the odds. The company was formed in 1993 by Washington State businessman Walt Kistler, a man with a passion for space and a founder of Kistler-Morse Corporation, maker of scientific and industrial instruments. His original idea was a stubby cone sporting a big square frame mounted around its perimeter.

Hung on the frame were to be four booster rockets. In 1995, Kistler hired Los Angeles business consultant Robert Wang as chairman to beef up his staff and run things professionally. Wang asked around to learn who might be available. The answer: Try George Mueller.

The semi-retired NASA veteran, who was living in nearby Santa Barbara, had been intrigued by reports of a gigantic satellite launch market looming like a tidal wave. He agreed to get involved, and took the design out to the town of Mojave for a consultation with airframe builder Burt Rutan. Rutan's company, Scaled Composites, has a hand in several of the new ventures, which seek his expertise with lightweight structures. He calls himself the Fisher Body Works of the small launch business.

The original Kistler design was a non-starter. "We actually got a few pieces of the original built with Rutan, but then we ran a few simple control calculations. We figured it would be flying sideways half the time," Mueller recalls.

But the company had real money—by the end of last year it already had

some \$220 million in hand, more than any of the other startups. Much of its financial muscle comes from the backing of John McCaw, brother of Craig, who made money from the 1994 sale of the family cell phone business to AT&T for \$11.5 billion. Mueller could afford to start over.

First he brought in some fellow veterans from NASA, including Dale Myers, a former agency deputy administrator, and Henry Pohl, an engineer who cut his teeth on the Redstone and Jupiter missile programs in the 1950s. The executive vice president, Dan Brandenstein, has flown four times on the shuttle, three times as commander. Vice president and deputy program manager Joseph Cuzzupoli was in charge of shuttle construction at Rockwell International, and before that managed several Apollo flights.

"Then we hired about six recent grad-



uates of the University of Washington aerospace program," Mueller says. The kids, he explains, can work all night while the old guys get some sleep.

Kistler managers expect to start test flights later this year from a commercial spaceport being built under a Department of Energy permit at the Nevada Test Site, where atomic weapons used to be exploded. Rutan's company is out of the picture now, with Northrop Grumman, Lockheed Martin, and GenCorp's Aerojet division under contract to build the new, totally redesigned K-1 vehicle.

It's a conservative design, with two stages that together can carry 10,000 pounds to low Earth orbit. Three NK-33s will go on the first stage, and one NK-43 on the second. A total of 46 Russian

rocket engines already have been delivered. Aerojet bought them for about \$1.4 million each, a fifth what a comparable engine from a Western company would have cost. American hydraulics and electronic controls are being added, but the big, tough Russian cores and high-pressure injectors remain intact. Kistler has a contract to buy the whole lot from Aerojet after they're modified.

As envisioned, a K-1 flight will be almost fully automatic, with no people on board. The first stage would take the

vehicle to about 130,000 feet, some 25 miles downrange. After separating from the second stage, it would relight its NK-33 engines, loop back, and descend on six parachutes back to the launch site. Touchdown is to be cushioned by big airbags.

The second stage will deliver the payload to orbit, then reenter and make its way by parachute and airbag back to Earth. The goal is to deliver satellites for about \$4,800 per pound, 40 percent under today's average price.

The parachute and airbag landing

systems work just fine, says Mueller. "We've been doing tests, dropping dummy stages out of airplanes. They come in and land—*shmoosh*—and they're there. It'll work." He figures he can get at least 100 flights out of each vehicle. "But we couldn't build those things without those engines." Thinking of the star-crossed Soviet N-1, he muses, "It's the first time in history the engines were so far ahead of the rest of the vehicle."

Those engines, the cash already in hand, a \$100 million launch contract signed with Globalstar, and Kistler's

## Rocket-on-a-Rope

COMPANY: Kelly Space and Technology

BIG IDEA: Spaceplane towed part way to orbit

Mike Kelly figures that if gliders full of troops could be towed behind transport aircraft during World War II—half a century ago—then a jumbo jet should be able to pull a rocketship part way to space. He'd like to prove it by sending a two-person reusable Kelly Eclipse Astroliner into orbit, sometime around 2001.

Kelly, a Purdue-trained aeronautical engineer and former missile designer for TRW (his boss was Dan Goldin, who went on to head NASA), first announced his scheme in October 1996. Less than a year later, he, his partner Michael Gallo, and a small team working out of the nearly empty San Bernardino International Airport (formerly Norton Air Force Base) in California dragged a small, homebuilt, delta-wing airplane called a Dyke into the air behind a Maule glider towplane. That trial was to be followed early this year by tests at NASA's Dryden Flight Research Center in California. For these Air Force-funded tests, a four-engine C-141 transport was to tow a 40-year-old F-106 Delta Dart interceptor, once the world's hottest fighter, into the desert sky using a 700-foot-long tether.

Assuming the tow system checks out, Kelly will press on with plans for subscale versions of its spaceplane, which a separate company called Eclipse wants to enter into commercial service as early as this year. If the financing comes through, Kelly would then build the full-scale Astroliner. It would be about the size and shape of a space shuttle, but with wider wings to get it off the runway fully fueled with liquid oxygen and kerosene, plus an 8,000-pound payload.

A typical Astroliner flight would begin with a tow off the ground by a Boeing 747. At an altitude of around 25,000 feet and a speed of about 575 mph, the Astroliner's pilot would cut loose from the tether and fire Soviet-designed RD-120 rocket engines in the vehicle's tail. At 400,000 feet the nose would open to release the cargo and its own attached liquid-fuel booster stage. While they headed for orbit, the Astroliner would coast up to 600,000 feet, then settle back into the atmosphere. Twenty minutes after takeoff, it could be back on the ground. Or it could take another 40 minutes to deliver a package as far as 6,000 miles away.

Most of the estimated \$250 million needed to

build one vehicle and get it into commercial service is supposed to come from loans, stock sales, and private investment. As of late last year, the company had raised about \$9 million, with commitments for more if it can sign firm launch contracts.

Like any startup, the business plan paints a rosy future. Kelly and his partners think they can grab more than half the market for small satellite launches by the year 2006, with 51 launches that year. By charging \$10 million to \$15 million per flight—or less than \$2,000 per pound to low Earth orbit, compared to the \$6,000 to \$10,000 charged today—in would roll \$600 to \$900 million annual revenue.

That, of course, is big talk from a company with a couple of dozen employees working out of a nearly abandoned Air Force base. But the managers of Motorola's Iridium project believe Mike Kelly has half a chance, and have given him a contract for at least 10 Iridium launches. No money up front, though—he has to get the rocket ready first to see any cash.

Kelly is a practical engineer, but he has his dreamy moments too. "We are at the greatest pregnant pause in history," he says. "Human emigration is entering a new phase. We've had these big waves, out of Africa, out of the Old World, and it took 300 or 400 years [for Western civilization] to cross all the oceans. We had the settling of the West here. But now we're off on the last step, the big one that goes on forever."



COURTESY/DIGITAL EMPIRE

veteran management team make the company a provisional favorite among the new rocketeers. But Mueller is not the only old-timer who exudes a young person's optimism.

"When commercial space gets really going in a few years, government spending will be just a fart in a wind

storm," says Pete Conrad, a 67-year-old former Apollo astronaut and now president of Universal Space Lines in Newport Beach, California (see "AnyRocket, Inc." p. 57).

After he left NASA and went to work for McDonnell Douglas, Conrad remembers urging his employers to put

money into far cheaper reusable rockets. The reply he got opened his eyes. "They asked me why they should make cheap rockets when they were selling all the expensive ones they could make." Similarly, Robert Zubrin, founder of Pioneer Rocketplane (see "Son of Black Horse," p. 58), remembers being brushed

### The 1998 Hudson

COMPANY: Rotary Rocket  
BIG IDEA: Space Helicopters

A dozen men sat around a conference table at the offices of Scaled Composites, Inc. in Mojave, California, listening to Gary Hudson's pitch. At one point in the presentation, Burt Rutan, famed aircraft builder and Scaled Composites' founder and president, leaned forward and exclaimed, "Wow! That's a neat idea.... It's a dynamite idea!"

Hudson, president of Rotary Rocket Company of Redwood Shores, California, just about burst. He needs an estimated \$100 million to build his vehicle, called Roton. He has maybe \$6 million in hand, some of it from techno-thriller writer Tom Clancy. Today, after arriving in a rented Learjet with several of his company's top officers, he was hitting testimonial pay dirt. This was a fund-raising trip, and Rutan, Exhibit A, was recalling the first time he heard of the rotary rocket. Their guest of honor: an investment banking chief for a very large international finance house.

The banker was giddy later as he looked at a small engine test facility Hudson's company has built in a metal shed on the fringe of the Mojave Airport. A new reinforced-concrete foundation showed where a larger test site was being prepared.

"This is going to be a commodity market," the banker said. "The cheapest price wins.... This looks to me like the most promising idea in the lot, if the idea is to really grab this small launch market."

It's also the most peculiar one. It will sprout rotors and hover like a helicopter.

Hudson and his chief technology officer, Bevin McKinney, have been developing the idea for several years. The single-stage orbital vehicle would have in its tail a centrifugal aerospike engine, an engine as odd as its name. An aerospike is like a conventional rocket, but inside out. Rather than expanding exhaust through a bell-shaped nozzle, flame erupts from the engine's perimeter. This "open" exhaust plume automatically adjusts to decreasing atmospheric pressure as the vehicle climbs. Theory holds that this should be more efficient than conventional rockets.

If the design works, the ring of flame at the base of the Roton will emerge from a circular frame spinning 715 times a minute, like a Fourth of July pinwheel. Centrifugal force will deliver the kerosene and liquid oxygen propellants at high pressure, eliminating the need for bulky pumps. That alone reduces the engine's weight by 30 to 50 percent.

Aerospikes have been tested on the ground since the 1960s, but nobody has ever used one for a working rocket. Either Roton or NASA's X-33 will be the first.

Stranger still are the rotor blades on the vehicle's nose. In this first version, they are used only for landing. They will be folded back flat along the 55-foot-high vehicle on the way up. For the Roton's fiery tail-first reentry, the fiber composite



blades will fold the other way, straight up from the nose, as the vehicle slows from 17,000 mph to a few hundred miles per hour in freefall. At around 20,000 feet, the idea goes, the blades will change pitch, start spinning, and extend under centrifugal force. The craft would slow, hover briefly a few feet off the ground, then land.

In later versions, Hudson wants to combine the spinning engine for take-off with the spinning rotors for landing by putting combustors on the tips of the rotors and sending the thing into the sky as a shrieking whirlybird of flame.

If he pulls it off, Hudson, 47, will have finally accomplished what he's been aiming at for most of his professional life: to get into the space business. A self-taught engineer (he dropped out of the University of Minnesota), he's been designing new rockets since the early 1980s, with names like Percheron, Liberty, and Phoenix. Each time, he raised a million dollars or more but was unable to bring a completed vehicle to market.

Asked how long it will take, after Roton or some other cheap rocket actually starts flying, before space will become a truly vibrant commercial arena and tourist destination, Hudson offers a bold prediction. Starting about 2010 or maybe 2012, he says, "The growth rate of people permanently present in space will be in the range of 25 to 40 percent per year for decades."

off after extolling an idea for a cheap, reusable rocket to his then-employers at Martin Marietta. "You don't understand," he was told. "We make *Titans*." And the government-subsidized Titans were making money.

In this crowd, scorn runs high for Big Aerospace, supposedly populated

by executives who are constitutionally unable to take chances and are addicted to feeding at the government trough. (Never mind that Conrad's and Zubrin's companies both have gotten seed money from NASA's Bantam program, which was set up to foster technology for small, cheap launchers.)

The new rocketeers' defiant attitude was on display last July in Washington at a motivational meeting titled "Cheap Access to Space," which featured presentations by several of the upstart companies. Rick Tumlinson, president of the private Space Frontier Foundation of Nyack, New York, set a messianic

## AnyRocket, Inc.

COMPANY: Universal Spacelines  
BIG IDEA: Airline-style operations

Pete Conrad emerges from a glassed-in conference room at the headquarters of Universal Space Lines, an upscale office on a tree-lined street near John Wayne Airport in Orange County, California. He's just met with representatives of Alaska Aerospace Development Corporation, which plans to build a spaceport on Kodiak Island, a 3,760-square-mile home for monster brown bears in the Gulf of Alaska. Two years from now, Conrad figures to be launching rockets from there.

The ex-astronaut has logged his share of time in both the public and private sectors. In 1973, after nine years in the Navy and 11 more with NASA—including four space missions and a trip to the moon—he went into the cable television business. Then he signed on at McDonnell Douglas. Selling airliners and fighters to the overseas market, Conrad learned how business works. "It's nothing like NASA, and nothing like the military procurement side," he says. "It's tough, and you have to compete and take

chances. You don't get paid for trying. You get paid for winning."

One fateful day in 1990, walking down the hall at McDonnell Douglas, he ran into the manager of the Star Wars-funded DC-X experimental rocket program (see "Single Stage to...Where?", Feb./Mar. 1994). "The more I learned, the more excited I got," he says. "I was as excited as I'd been for Apollo."

For the next six years, Conrad did nothing but DC-X. He fell in love with the idea of a rocket so light and simple it could be flown twice in one day and could be maintained by just a dozen people or so. He piloted the rocket from a trailer, with a few computer displays and a mouse. The little dunce cap of a vehicle, blue fire flickering from its four engines, floated down to a vertical landing just like the rockets Conrad read about in science fiction stories as a boy.

When the DC-XA program—NASA's successor to the DC-X—ended in 1996, many members of the team followed him over to his new venture. Universal now has \$4 million in contracts, including subcontractor work for several NASA and Air Force reusable-rocket research programs.

Conrad and his team want to fly reusable spacecraft. If there were any out there to buy, they'd buy 'em—the company is more interested in operations than in manufacturing. But other startups haven't even built their vehicles, much less started selling them. To get into business fast, Universal's in-house hardware maker, Rocket Development Company (its president and CEO is James French, Apollo lunar lander descent engine designer), plans to make the world's dead-simplest throwaway rockets. Dubbed Intrepid I and II, they are designed to be launched by as few as 10 people.

The two-stage Intrepids would be built at company facilities in Las Cruces, New Mexico, where many of the employees are, like Conrad, ex-engineers from McDonnell Douglas. If the company is right in its projections, Intrepid I will be able to deliver nearly 1,000 pounds to low Earth orbit for under \$6 million, less than half the cost of other rockets its size. Intrepid II would have a larger first stage and would be able to deliver 5,000 pounds to low orbit for about \$10 million.

Conrad hasn't lost the love he felt for the straight-up, straight-down DC-X, and he still hopes to get his hands on a grownup version. Last September the McDonnell Douglas Space Division, now a subsidiary of Boeing, won a \$4 million, 18-month Air Force contract to determine whether a military spaceplane could be mounted on a larger version of the vehicle. If that leads to a commercial rocket, Conrad has the inside track on operating it.

He can already picture how it will be 15 years from now when Universal is the UPS of space. "We pick up a package, go suborbital to a destination halfway around the world. Then we go out to geo [geosynchronous orbit], deliver a package, and drop back to Mexico City on the way home. That sounds like airplanes to me. That's how it'll work."



tone from the start. "Welcome to the revolution!" he boomed from the mike. "It begins here, and it begins now!"

Tumlinson is representative of a raucous chorus of space enthusiasts, the kind who believe in the manifest destiny of human expansion off the plan-

et. They don't want any more nationalistic space spectacles like Apollo. No more flags and footprints. They want Rockets for the Rest of Us, rockets as dumbly reliable and reusable as pickup trucks, rockets that will make money, yes, but also rockets for tourists,

rockets to expand humanity gloriously into space.

Peter Diamandis, founder and president of the St. Louis-based X-Foundation, hopes to help jump-start the exodus by handing over a check for \$10 million, along with a bronze trophy, to

## Son of Black Horse

COMPANY: Pioneer Astronautics

BIG IDEA: Aerial refueling of a spaceplane

Mitchell Clapp was an Air Force captain and test flight engineer in 1995 when he quit to pursue the private-rocket business. He'd been interested in space most of his life and had even applied to the astronaut corps. But his big break came in 1991, when the Air Force trained him to "fly" by remote control the DC-X and DC-XA reusable rockets. That set him thinking about other ways to reach space cheaply.

Thus was born, on a bar napkin at the White Sands officers club (he still has the napkin), what he came to call the Black Horse concept. He liked the idea of landing the same way you take off, but not like the DC-X. "You'd be landing vertically on a pillar of fire," he says. "If it restarts, you have 30 seconds to land. If it doesn't, you have three seconds to die."

That left airplane-style. But he ran into the same problem faced by all designers of single-stage-to-orbit rockets: The ship needs to be more than 90 percent fuel by weight, leaving little or no room for cargo. Clapp's idea was to leave some of the fuel—or rather the oxidizer for the fuel—behind. By tanking up in the air like an Air Force bomber, he figured he could shave 15 percent off the mass that had to be lifted from the ground. And that, he says, is enough wiggle room to add a payload.

His Black Horse vehicle, the size of a fighter plane, was designed to satisfy the Air Force's wish for a quick way to get a pilot and small payload to space, without extensive ground facilities. The concept was given high priority in *Spacecast 2020*, a report on goals for the Air Force. But then nothing happened. "Not too many ideas from captains actually get built," he says. His frustration mounted.

In July 1993, Clapp presented a summary of his concept at an aerospace meeting in Monterey, California. There he ran into Robert Zubrin. They talked over Clapp's idea—again, at a bar. Zubrin was intrigued. "It struck me as novel, as very clever," he recalls.

Today, Zubrin is best known for innovative strategies to get human expeditions to Mars (see "Mars Direct," Apr./May 1994). But in 1993, he was just a restless engineer at Martin Marietta Astronautics in Denver. Zubrin went home to Colorado and analyzed the concept of aerial propellant transfer "six ways to Sunday." He liked it but suggested changes. There seemed no good reason, for example, to force the spaceplane to travel all the way to orbit right out of the box. If it merely got above the atmosphere, Zubrin figured, a small expendable booster could take commercial payloads the rest of the way.



Months went by, and the Black Horse remained an idea on paper. Zubrin found himself shut out at Martin Marietta, where he felt managers were happy to keep building expensive Titans forever. So he incorporated Pioneer Rocketplane in the basement of his Denver home.

Since then, Clapp's basic idea, now called Pathfinder, has gone through several redesigns. And the company has grown, with offices in a professional building in Lakewood, a Denver suburb. Clapp is setting up a second office in California near Vandenberg Air Force Base, where he hopes to start flight tests in 2000.

Like other fledgling rocket companies, Pioneer needs cash—about \$100 million—to fly. So far, only about \$3 million of study money is in hand, most of it from NASA. To get the rest, Zubrin has stepped down as Pioneer's president to become chief scientist and has hired a set of officers more likely to impress potential investors. They include retired Air Force general Merrill A. (Tony) McPeak as chairman. McPeak was Air Force chief of staff when Clapp came up with Black Horse. The new president and CEO is Lawrence Hecker, a deputy administrator of the Federal Aviation Administration under Ronald Reagan and a former senior vice president for flight operations at TWA.

Zubrin isn't sure how he'll get the rest of the money, but the company is considering selling stock. Ever optimistic, he says, "We can build this vehicle for less than what Hollywood spent on *Waterworld*." Reminded that the movie was a flop, he adds, "That's the point. If society can take chances on movies, it ought to be able to take a few chances on getting into space cheaply."

the first builder of a private, reusable passenger spacecraft. To win, one must fly a piloted craft to an altitude of about 62 miles, land the thing essentially intact, then do the same thing again with the same vehicle within two weeks. Only one person has to be on board, but the spacecraft must be able to carry two additional passengers (198 pounds apiece). No governments need apply. To qualify, competitors must build their vehicles without any substantial taxpayer subsidy.

The trajectory won't differ much from the suborbital hop flown by Mercury astronaut Alan Shepard in 1961. And the \$10 million award—only a tenth of which Diamandis has been able to raise so far—is unlikely to come close to covering the cost. Most of the startup rocket companies expect to spend at least ten times what the prize is worth. But a few have signed up anyway.

Meanwhile, they plug away on more pragmatic matters, like trying to raise real capital and build real hardware. They know the long odds they face. For one thing, the market may never materialize. The entire low-Earth-orbiting communications satellite business could go bust, shouldered aside by fiber-optic cable networks on the ground. Existing rockets—Deltas, Arianes, Long Marches, Protons, Zenits, and half a dozen more—could end up hogging all the business for themselves, particularly if the upstarts can't reduce launch costs as much as they think they can. And government agencies like the Federal Aviation Administration, which is still wrestling with the question of how to license rocket companies that operate like airlines, could bury them forever in red tape.

The killer for any or all of the startups might be technical setbacks that force development costs up or timetables back. One launch pad fireball could do it. "The issue...is whether their investors will stick with them long enough



*Left: Kistler's team of young engineers, according to their boss George Mueller, can work all night while the old guys get some sleep. Below: The K-1 vehicle will return to Earth with parachutes and airbags.*

their money to keep going, because they have not been able to produce viable systems at this point." But like many on the sidelines, Williamson figures one or two of them have a shot. And if they do succeed, "it would show for the first time that you don't need large infusions of federal cash to make launch systems work."

Among those rooting for the new guys is NASA Administrator Daniel Goldin. He would rather someone else worry about putting things in Earth orbit while his agency focuses on exploring the universe and developing experimental "X" vehicles that spur on private business to build even better operational spacecraft.

"We will applaud when they take off and we can get out of the launch business. We will applaud when they get rich," Goldin says. "We will applaud." And then he adds, "But we would like them to do more, and talk less." ➔

to get into the marketplace in a serious way," says Ray Williamson of George Washington University's Space Policy Institute in Washington, D.C.

"Some of these people have been around a long time," he continues. "Gary Hudson (see 'The 1998 Hudson,' p. 56) has been trying for years and years. It's a puzzle to me where he and others get



JAMES CASTLE



*S*now was coming. The fabric covering the hangar flapped like a frigate's topsails in a gale. A powerful late-spring storm was bearing down, and the temporary building at the Stratford, Connecticut airport groaned and rattled as if it was getting ready to take off.

Phil Spalla glanced nervously at the makeshift roof. The director of the recently formed Igor Sikorsky archives, Spalla had brought me out here to meet Sergei Sikorsky, son of Igor, the great Russian aircraft designer. Sergei was unfazed by the gathering storm. The eldest son and the only one of Igor's five children to go into aviation, Sergei is now retired from Sikorsky Helicopter, having finished a long career that began on his father's lap as an unofficial test copilot. A compact, hugely ener-

getic man in his early 70s, Sergei had spent thousands of hours in cockpits, test bays, and hangars, shouting above the din of engines and machinery. He had little trouble making himself heard over a developing blizzard.

Inside the building, a slender little biplane with a jaunty tail was taking shape. It was still just a skeleton, with no fabric, no engine, and no wheels. The upper wing was suspended from a horizontal ladder chained to the ceiling. Eventually the skeleton would become a replica of a Sikorsky S-16, a fighter/scout aircraft that flew in Russia from 1915 to 1924.

Sergei began to tell me about the replica's complicated past. "The story probably starts with a personal friend of mine living in Russia," he said. The friend, Vadim Mikheyev, worked at the

*In a temporary hangar where volunteers are restoring another Sikorsky aircraft, the S-16 replica was finally completed after a rocky start in the Soviet Union. The S-16 dates back to pre-revolutionary Russia, but fortunately a Sikorsky aficionado was able to uncover detailed plans for the 1915 fighter.*

company that makes Mil helicopters, and in his spare time he conducted research on Russian aviation history.

Before the fall of Communism, such a pursuit would have been dangerous. After the 1917 revolution, the Bolsheviks set out to expunge the name "Igor Sikorsky" and those of other pre-revolution aviation figures. As Von Hardesty of the National Air and Space Mu-

# Igor Sikorsky's

# Little Bird

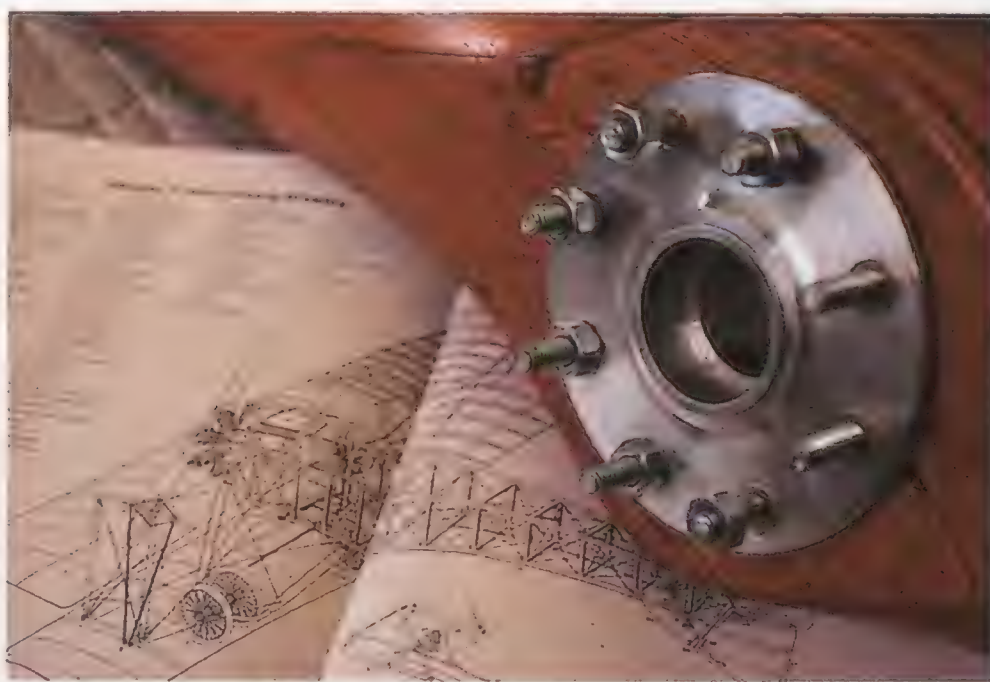
From the rubble of Communism,  
a long-lost design is  
being brought back to life.

by John Fleischman

*Photographs by Brad Trent*

seum explains it, Sikorsky represented something that could not exist under Communist ideology: modern technology in pre-revolutionary Russia. After the revolution, Sikorsky was forced to leave; in 1919 he emigrated to the United States, where he was able to continue his aircraft design work.

Though public mention of Sikorsky in the Soviet Union was essentially forbidden, his work was so admired by aeronautical engineers there that they kept it alive, passing on references to it in secret. Recalled Sergei: "My first visits to Russia were about 1965 or so, fairly early in the game. I was very much touched that even though



it was still the Brezhnev era, the Sikorsky name was not forgotten. It was embarrassing, sometimes very heartwarming, but in the aviation community, bar none, the name of Sikorsky was almost a religious name."

Archivist Spalla added, "A Sikorsky [company] engineer came back from

one of these early trips to Russia with Sergei and said that it had been like traveling through England with Mick Jagger."

Throughout the 1980s, Sergei's friend Mikheyev traveled throughout the Soviet Union, visiting Moscow, Kiev, and St. Petersburg in quiet pursuit of Sikorsky material. Fortunately, said Sergei, "the

Russians never threw anything away. They classified it 'top secret,' then threw it into a drawer and forgot about it."

When Communism started to crumble in the late 1980s, Mikheyev was able to pursue his interests a little more openly. As word of his research spread, he made friends with a group of young en-

gineers who were working on the Buran, the Soviet Union's space shuttle project. They were building the shuttle at a secret factory north of Moscow, and some of the engineers had formed an aviation club there.

One engineer, a man named Mikhail Korenkov, had belonged to another aviation club, and had helped it build a replica Sopwith Camel. Recently, he had gotten permission from the cash-starved Buran factory to pursue a similar undertaking—the manufacture of flying replicas of World War I aircraft.

The funding was to come from a novel source—a native capitalist, what's been dubbed a New Russian. This investor believed replicas of vintage aircraft would sell well to museums in the West. "This New Russian comes to the [Buran] design bureau and says, 'Let's build some airplanes. Let's build a Nieuport 17,'" recalls Mikheyev. "I told them that a great number of foreign museums have a Nieuport replica but they would not have any Sikorsky airplane."

Mikheyev suggested that the club build a replica of Sikorsky's S-16. Mikheyev had unearthed a set of original production drawings of the aircraft that the team could work from. The original S-16s had been powered by several different rotary engines—a 110-horsepower LeRhône, an 80-hp Gnome—but Mikheyev suggested using a modern Russian 180-hp M-3 or M-11 radial. Both were widely available, and both could provide more power for a flying replica. The investor agreed to Mikheyev's suggestion, and in late 1989 the Buran factory's aviation club started work on a flyable S-16.

Mikheyev's choice was a good representative of Igor Sikorsky's early genius, says Von Hardesty. The curator points out that Sikorsky's Russian work runs along three paths: helicopters, which he gave up on until moving to the United States; the Il'ya Muromets, a four-engine bomber used in World War I for strategic raids on East Prussia; and the S-series of biplanes. "The S-16 was the most successful of the S-series," Hardesty says.

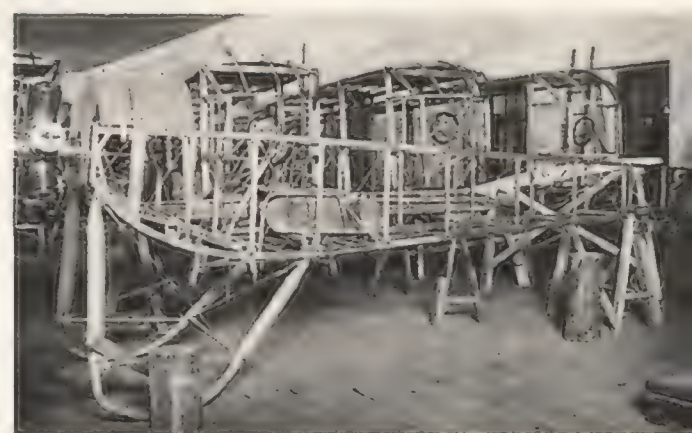
The S-line represents one of the most rapid aeronautical self-educations in history. It took Sikorsky from theory to mastery in only three years. The series still amazes Sergei. "I think he was



COURTESY IGOR I. SIKORSKY HISTORICAL ARCHIVES, INC. (5)



averaging one new aircraft every four to six months," he says, "which meant designing it, building it, test flying it, repairing minor crashes that would take it out of operation for one or two weeks. Finally he would get another 18 or 20 seconds of flying time teaching himself to fly before he crashed again. Every six months or so, he'd suffer a major crash that would damage the aircraft beyond any hope of repair. They'd salvage the engine and the prop and by this time he advanced a little and he'd say, 'This time we're going to do it a little differently, a little different wing area or a little this or a little that.' Dad's fa-

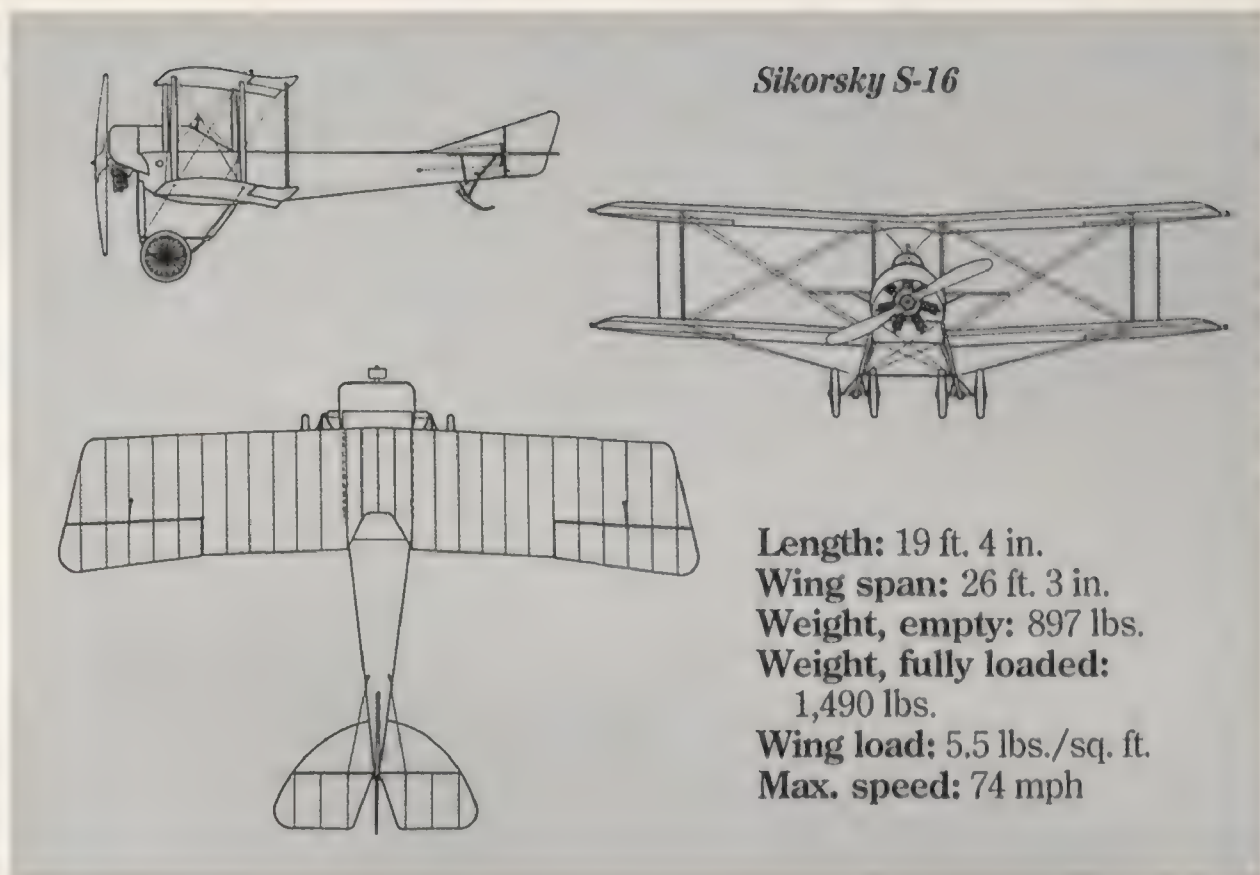
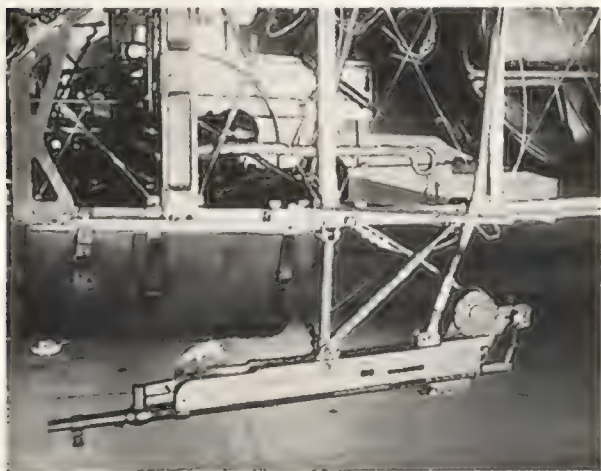


*Above: This rare photograph shows an S-16 under construction at the R-BVZ (Russo-Baltic Wagon Works), the company that built all of the aircraft Igor Sikorsky (left) designed in Russia. Top: Present at this inspection of a pre-production S-16 was General Mikhail Shidlovsky (at far right), the commander of Russia's Squadron of Flying Ships and also the chairman of the R-BVZ.*

vorite phrase for that was 'incremental engineering.' "

The S-16 distilled Sikorsky's learning in one single-engine biplane. Designed as an escort for Il'ya Muromets bombing missions, it first served the Czar's air force and last flew for the Bolsheviks in the Russian civil war. The S-16 was the first Sikorsky fighter with a machine gun synchronized to fire through the propeller without hitting

The S-16 was the first airplane equipped with a synchronized-firing system: A machine gun like the Colt-Browning below was supposed to fire in synch with the propeller's revolution but didn't always do so. Bottom: Fitted with a stalwart pair of skis, the S-16 could fly in all but the harshest days of the Russian winter.



IAN STAIR (FROM THE IMPERIAL RUSSIAN AIR SERVICE)



the blades. It was also the first Russian fighter actually built in Russia.

At the Buran plant, the aviation club members fashioned wings and control surfaces from wood. But they could not find enough ash—the wood Igor Sikorsky had used—to craft the fuselage, so they opted for stainless steel. They fabricated the distinctive landing gear, which Sikorsky had designed with four wheels instead of the usual two to help it move over soggy Russian fields. A vintage Vickers machine gun was located. Then the financial roof fell in.

Recalls Mikheyev, "Suddenly our new sponsor has not money to pay us

and we had not money to finish the Sikorsky airplane."

By then Communism was collapsing; the Buran program also ran out of money, and the factory was abandoned. Inside the huge, dark building stood five massive assembly jigs built of steel girders. Each contained a Buran airframe at some stage of construction. The one closest to the door was about 90 percent done.

Only after you had passed the last shuttle and turned left would you finally come upon the unfinished S-16. There it stood, as charming and vulnerable as a little bird.

In 1993 Mikheyev asked Sergei Sikorsky whether his company would be interested in buying the orphaned S-16, which was about three-quarters complete. Sikorsky Aircraft had already entered the restoration business when it undertook the rebuilding of a Sikorsky VS-44 flying boat. Sergei was very interested, but first he would have to persuade the company. Before he could do that, though, the situation at the Buran factory turned critical.

The charade of building a space shuttle was over and the factory was ordered cleared. The directors lost all patience with New Russians with no cash. The factory director ordered the team to pay for the cost of building the aircraft and get it out of the factory. The unfinished S-16 was hastily crated up and driven to a shed 50 miles north of Moscow. Soon after, the S-16 builders scattered, Korenkov going off to a new private design bureau to work on light aircraft.

While Sergei lobbied for the S-16 in the States, the little bird wandered the netherworld of post-Soviet entrepreneurship. It changed hands and locations several times (mostly barns and sheds around Moscow). All the while, Mikheyev watched over the crate, making sure it was at least covered to protect it from the snow.

Finally, last year, salvation arrived. The president of Sikorsky Aircraft, Gene



Buckley, approved the concept of a Sikorsky archive for artifacts and documents representing the company's rich past. A building was tentatively selected to house a small museum and research facility, and with funding through the archive, Sergei was told to go rescue the S-16.

"When we got the green light," Sergei recalled, "we had the S-16 moved to the Moscow International Airport, where Lufthansa runs a weekly air freight service into and out of Moscow." In Moscow, the local office of United Technologies, the parent company of Sikorsky Air-

craft, helped with the formidable task of getting the S-16 shipped out of Russia. Last winter, the little bird finally landed in Connecticut.

The responsibility for finishing the replica fell to Pete Peterson, a retired Sikorsky shop foreman who for years had been restoring and replicating old aircraft as a hobby. Last spring, Peterson recounted the challenge he and his crew of volunteers faced. The Russian workmanship "runs the full gamut from the poor to the good," he said. "The ailerons were a complete loss. They were all cut to different lengths and we

had to rebuild them. The wing ribs and spars were all right." As for the fuselage, several winters under tarps and several moves by freelance forklifters had left it slightly twisted. And the wheels had vanished in transit from Russia.

The top wing was made of two panels, and the crew joined them together with connecting plates. Then they fabricated and installed the top aileron cables, pulleys, and brackets. Though the original S-16s were covered in linen, Peterson's crew chose to use Dacron. "The difference between the linen and the Dacron cloth is that the Dacron will

be here after we're gone," Peterson explained. "It lasts virtually forever. It's a synthetic that's not vulnerable to mildew and sunlight." Linen and cotton, on the other hand, have to be replaced every seven to 10 years.

The crew applied the fabric to the airframe using a nitrate doping material as an adhesive. Then they tightened it with a clothes iron and hair dryer and treated it with two coats of the dope. For the wing and tail, they laboriously stitched the fabric onto the ribs so it wouldn't balloon in flight.

Peterson's crew was putting many hundreds of hours into the project. A few of the volunteers were Sikorsky retirees, and all, said Peterson, were "airplane nuts." "Look at Rich Carlson," he pointed out. "He still works at the Bic Pen Company. He comes in here real early, works for three hours, and then he goes to his office at Bic."

The big decision facing the S-16 team last spring was whether to try flying it with an authentic 80-hp reconditioned LeRhône. Is the metal fuselage too heavy? Said Peterson, "With an 80-horsepower LeRhône it gets awfully close. With a 180-horsepower engine [the fuselage] would not be too heavy."

Harry Pember, the president of the Sikorsky archives, cast the deciding vote. "The metal fuselage that was fabricated in Russia was fine, but somewhere between here and there it got twisted," he explains. "It's not the weight per se or the materials, but we can't straighten it out. Now Pete Peterson, who's in charge of this thing, has put together 40 of these [restorations], and he says, 'I wouldn't fly it.' That's good enough for me."

Gene DeMarco at Old Rhinebeck Aerodrome in upstate New York has been discussing plans to produce an S-16 replica with a wood fuselage and an overhauled 80-hp LeRhône, says Pember. Then Sikorsky fans would be



able to see an S-16 fly again. But as for the little bird that rose from the rubble of the Soviet Union, it will be on static display, probably at the big Sikorsky Helicopter plant, the archive, or perhaps on tour.

Whether it flies next year or never,

the S-16 pierces the darkness that Communism had cast over early Russian aviation history. In period photographs, you can see Igor Sikorsky, a still-wet-behind-the-ears kid in a wing collar and pumpkin-shaped aviator's helmet, posing with the astounding aircraft he created in that vanished world. Here he is with his 1910 helicopter, which needed only an engine no one could build for another three decades. Or there he sits in a 1914 Il'ya Muromets, an enormous airplane with four engines, an enclosed passenger cabin, electric lights, heat, toilet, and a linen-covered wicker table on which the world's first in-flight meal—sandwiches and fruit—was served. The re-created S-16 brings that era to light again.

Last fall, Peterson's crew finished all the stitching, sanding, doping, and wiring. A non-operating 80-hp LeRhône engine on loan from Old Rhinebeck Aerodrome was installed, and the little bird, decked out in full Czarist cockades and tri-color pennant, was rolled out into the Connecticut sunshine. ➔



*Opposite: Archivist Harry Hleva (left) and Sergei Sikorsky review the progress on the S-16 replica at the Connecticut restoration facility. A team of volunteers (right) completed the work that had been started in Russia, attending to such details as the wing struts (above) and fabric doping.*

## Fortress Mentality

**S**teadily climbing air fares are becoming burdensome to consumers. As part of a trend that started over a year ago and shows no sign of ending, air fares rose 2.7 percent last September, and then another 3.8 percent the following month. The climb has been especially steep in business fares: Since February 1996, business air fares have increased 38 percent.

If left unchecked, such inflation could incite efforts to re-regulate the industry in a manner that would do great harm to the aviation system and the people it serves.

Since being enacted by Congress in 1978, airline deregulation has served the consumer well and its benefits have been extensively documented. For example, an April 1996 study by the Department of Transportation estimated that almost 40 percent of domestic passengers travel in markets with low-fare competition, saving consumers an estimated \$6.3 billion annually.

But the job of deregulation is not yet complete, nor are the fruits of competition fully realized. The early 1990s were financially tough for air carriers. Cost-cutting alone apparently was inadequate to stem the tide of red ink. Some carriers eliminated or scaled back their hub operations. Those that scaled back concentrated their efforts at their remaining hubs, where they dominated traffic. Many observers characterized this phenomenon as a retreat by carriers into "fortress hubs."

Initiated as a survival tactic, this practice has raised concern about the anti-competitive impact of fortress hubs. Low-fare carriers charge that their efforts to enter these markets have been defeated by the better-entrenched competitors, who can use higher fares on noncompetitive routes to subsidize their efforts. Indeed, competition at these hub cities has decreased. At over half of the nation's 25 busiest airports, more than 50 percent of the traffic is gener-

ated by one airline. We're now seeing the result: a sharp rise in fares at these cities, particularly in unrestricted fares to prime business markets.

The solution to this problem lies not in re-regulation but in further deregulation and the reform of anti-competitive policies remaining from deregulation's inception. To accomplish this, I recently introduced into Congress the Aviation Competition Enhancement Act of 1997. Of the act's three major initiatives, the most far-reaching takes aim at a key contributor to anti-competitive behavior: the existence of a quasi-monopoly on takeoff and landing slots at four large airports. (The bill's other initiatives include authorizing the secretary of transportation to make competition-enhancing exemptions to a rule specific to Washington D.C.'s National Airport and requiring the DOT to respond promptly to charges of anti-competitive airline behavior.)

The Federal Aviation Administration first assigned takeoff and landing slots to air carriers in 1968 as a temporary air traffic rule intended to relieve congestion at four airports designated as "high density": John F. Kennedy In-

ternational and La Guardia in New York, Chicago O'Hare, and Washington National. Today, nearly 90 percent of the slots at these airports—over 3,000—are owned and controlled by airlines or their predecessors that were in existence when the rule was imposed.

Since 1968, the so-called high-density rule has been modified several times and is under constant review, largely because of its temporary status. For instance, to ensure maximum use of the slots and, hence, the airspace, the Federal Aviation Administration in 1985 began requiring that carriers use the slots a minimum of 65 (later, 80) percent of the time for which they were scheduled or risk forfeiting them.

Over time, the slots developed into scarce commodities, and by 1985, it had become evident that the demand for them was exceeding supply. No longer able to reach voluntary slot scheduling agreements with the carriers, the FAA adopted a rule permitting air carriers to transfer the slots for monetary or other compensation. Ideally the market would eventually determine their distribution. To minimize disruption to air service during the transition to this new regime, the first allocations of these operating privileges went to the carriers holding the slots the day the rule went into effect: December 16, 1985.

Provided to the carriers free of charge, these so-called grandfathered slots represented a financial windfall. The General Accounting Office estimates their worth at approximately \$3 billion—nearly \$850,000 per slot. The carriers are allowed to buy, sell, and trade these slots among themselves, and the proceeds from these transactions remain with the carriers.

But the grandfathered slots have become a competitive windfall as well. The problem is that carriers formed after 1985 are obliged to purchase their slots from carriers who received theirs for free, placing them at a disadvantage and



---

## The air travel industry is growing anticompetitive; Senator John McCain outlines a change in course.

reducing the opportunity for competition. Furthermore, the carriers that hold slots are not inclined to sell them to their competitors at any price. The GAO testified before Congress that slot sales between financially related carriers—those with commuter affiliates, for example—increased from 14 percent in 1986 to 39 percent in 1988, while sales between unrelated carriers decreased a corresponding amount in the same period.

In addition, a lucrative market in leasing slots has developed, further benefiting carriers with grandfathered slots. By retaining control of the slots, these carriers also reserve the right to terminate the lease if, for example, the leasing carrier proposes to use the slots to institute competitive service. And short-term leases enable a carrier not using its slots to retain them despite the use-or-lose requirement.

This situation is having an impact on the consumer. According to the Department of Transportation and industry analysts, a “fare premium” exists at the high-density airports, particularly at O’Hare, La Guardia, and National, where fares run some 25 percent higher than at non-slot-controlled airports.

The Aviation Competition Enhancement Act would address this problem by allocating slots among “new entrant” and “limited incumbent” air carriers—air carriers that came into existence after 1985 and those that have never held more than 12 slots at a particular airport since then. This subset of carriers has asked the U.S. government for help in getting access to slots at controlled U.S. airports. Their arguments are much like those of the incumbent carriers who have asked for U.S. intervention to secure slots at capacity-constrained international airports such as London Heathrow and Tokyo Narita.

Under the bill, the secretary of transportation is to create slots wherever possible. Improvements in aviation technology, including air traffic control sys-

tem upgrades and the use of quieter aircraft, should allow some expansion of capacity at high-density airports while not breaching safety or noise standards.

In instances where new slots cannot be created, the legislation would require the secretary to withdraw a limited number of grandfathered slots that remain with their original carriers: up to 10 percent of this subset of slots ini-

Congress has an obligation to remove any artificially imposed barriers that retard airline competition.

tially, and five percent every two years following if necessary. The withdrawn slots would then be auctioned among new entrant and limited-incumbent air carriers. (Withdrawals would be made according to a random ranking assigned to the slots in 1968; slots used to service relatively underserved markets at small to medium hub airports would be exempt from withdrawal.)

While critics of the slot proposal have been quick to label it re-regulation, the legislation does not re-regulate the aviation system. Rather, it seeks to ensure that current rules and regulations are not abused by incumbent airlines in an effort to thwart competition.

Protectors of the status quo also ar-

gue that incumbent carriers have made investments in these slot-controlled airports and that any competitive threat to their preeminence would be unfair. Incumbents have made investments, but they pale in comparison to the taxpayer’s investment in the airport infrastructure. These federal investments were financed by all airline passengers via aviation excise taxes and airport-administered passenger facility charges. Passengers on all airlines are entitled to fair and realistic access to takeoff and landing rights at these federally funded slot-controlled airports.

While the reforms in my bill neither provide a panacea nor promise a perfectly competitive aviation industry, they do make needed improvements toward that end. Clearly in a free aviation market, not all cities will receive the same level of air service at the same price. Moreover, we cannot and should not guarantee that every airline will succeed. All carriers will and should leverage their unique advantages to provide the best service they can in a particular market. At the same time, they should not focus their market efforts on preventing others from doing the same. Congress has an obligation to ensure that doesn’t happen by removing any artificially imposed barriers that retard competition.

We are moving into the age of seamless, global aviation networks. The U.S. government has supported our carriers in the quest to have the opportunity to compete internationally through U.S. bilateral “open skies” agreements with other countries. It is only right that the U.S. government support and foster new competitive opportunities domestically as well.

---

A U. S. senator (R-Arizona) and former naval aviator, the author chairs the Senate Commerce, Science and Transportation Committee, which oversees aviation.

# STAR IN A BOTTLE

*For the tiniest fraction of a second, scientists can replicate the strongest forces in the universe.*

**by Billy Goodman**

**T**oshi Tajima is a member of a small club of scientists who specialize in a state of matter rare on Earth but, to put it in Earth terms, as common as dirt in space. Tajima studies plasmas, gases in which some or all of the atoms have been stripped of their electrons. Because they are made of charged particles, plasmas exhibit all kinds of interesting behaviors. For example, the northern and southern lights are the result of a plasma—the solar wind—interacting with Earth's magnetic field.

Stars are plasma too, but scientists have studied them primarily by analyzing the light radiating from their surfaces. Far more difficult is analyzing the interior of a star, where radiation emitted by the nuclear furnace in its center makes its way outward through a series of absorptions and emissions until it shines at the surface.

Tajima is a theorist, not an experimenter ("I break equipment," he says), but he believes that a revolution in astrophysics is at hand with the development of laboratory equipment that can create from solid material the very hot state of a plasma. With this equipment astrophysicists can for the briefest instant bring into the laboratory a tiny piece of a star.

The device is an extremely powerful, compact, short-pulse laser. Tajima calls such instruments T<sup>3</sup> lasers because they are small enough to fit on a tabletop, their pulses are measured in terawatts (a terawatt is 10<sup>12</sup> watts), and T<sup>3</sup> is easier to say than tabletop terawatt. T<sup>3</sup> lasers are not impressive to look at, and the energy they generate is 10 to 100 times less than that of the largest scientific lasers. But because the pulse they produce is so much shorter (measured in femtoseconds, which is what you get when you divide one second 10<sup>15</sup> times), T<sup>3</sup> lasers can be even more powerful than big lasers. Since energy equals power

multiplied by time, a given amount of energy can be delivered with an extremely powerful but brief pulse or a weaker, longer pulse. Another advantage of these small lasers, according to Tajima, is their high replication rates: Researchers can fire the lasers many times a second, compared to every two hours or so for very large lasers.

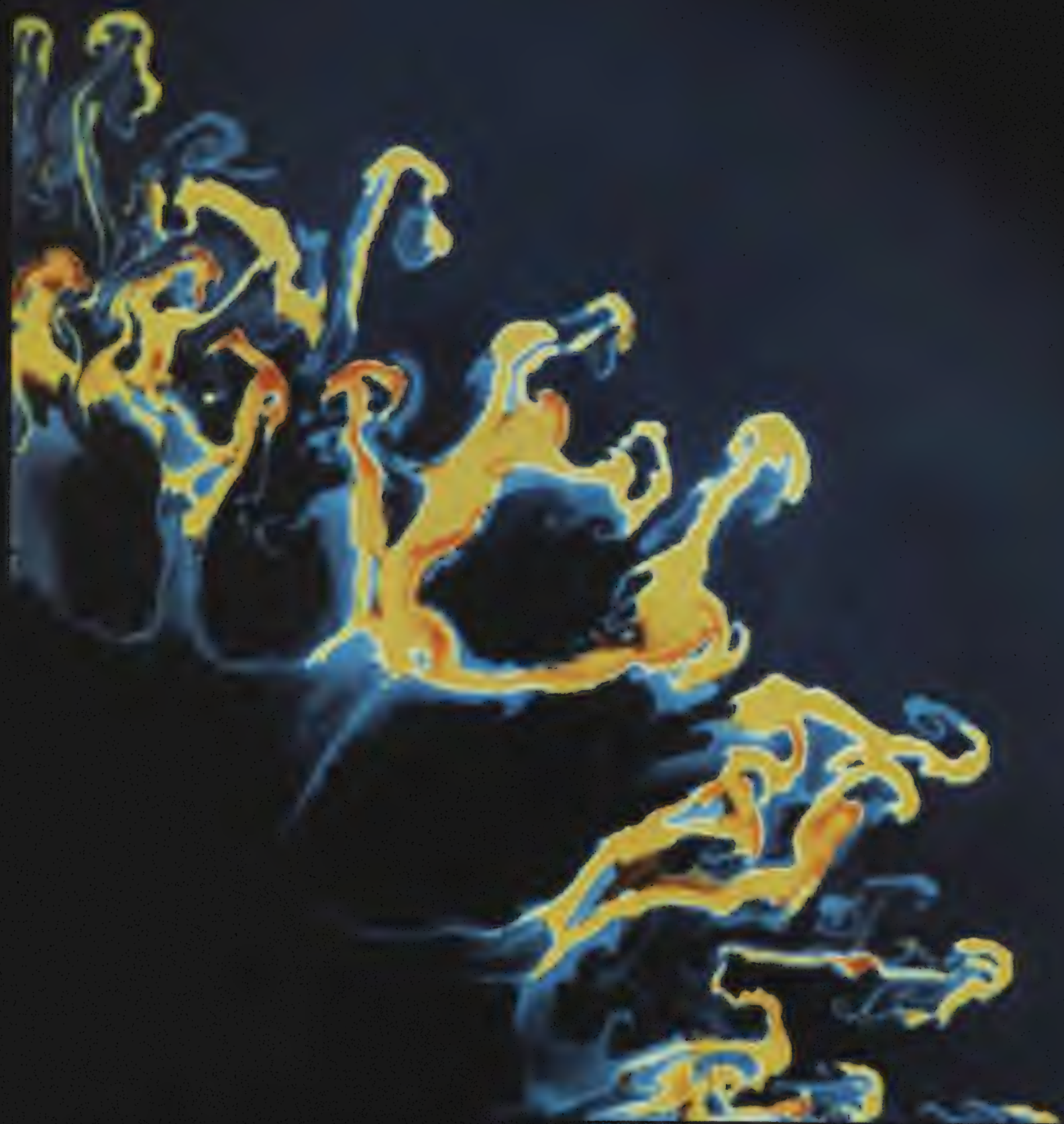
They are good at "creating violence on a local scale," says Tajima's University of Texas colleague Michael Downer. Downer has worked with carbon, an element difficult to melt using ordinary laboratory techniques. Yet Downer's graduate students used the laser to study the optical and material properties of carbon heated to a plasma state.

The carbon samples were only 100 microns across, slightly wider than a few hairs. "We heat the material so fast that it doesn't have time to thermally expand," says Downer. The material thus created may have the density of an ordinary solid, but its temperature puts it in the plasma regime—albeit a relatively cool plasma.

With pairs of pulses—the first called the pump, the second the probe—the students heated the carbon and measured its various properties. They established a table of, among other things, the opacity and electrical conductivity of carbon over a range of temperatures, important information for astrophysicists working on models of the transmission of a star's energy from its inside to its outside.

Tajima believes that the behaviors of plasmas could also be

*A computer simulation mimics the roiling of hydrogen and helium on the outskirts of a supernova. The model can now be tested by comparing it with the results of laboratory experiments.*





*A technician stands amid the 10 beamlines of the Livermore laboratory's powerful laser, Nova.*

key to understanding some of the most powerful phenomena in astrophysics, X-ray and gamma ray bursters—transient, extraordinarily energetic releases of radiation from nobody knows what (see “The Great Gamma Ray Mystery,” June/July 1993). Some experts believe these energetic photons may come from neutron stars. But Tajima believes there may be more than one mechanism to explain them, including one that requires the interaction of a hot, tenuous plasma with a black hole. Tajima proposes to test his theory with the little T<sup>3</sup> lasers.

The T<sup>3</sup>s are affordable (though not cheap) and represent a powerful tool for experimentation that many scientists can use. But they are not the first lasers to be used for astrophysics research. The power source for stars, nuclear fusion, has been the target of billions of dollars of research since the 1950s. By the beginning of this decade, funding for fusion energy had tightened, and, as time became available on expensive fusion research hardware, researchers began using the equipment for experiments in astrophysics. One of the most advanced facilities might be thought of as the T<sup>3</sup>'s older and much bigger brother. Its name is Nova, and it has already created the conditions found at the center of the stars.

Wearing ill-fitting shoe covers, a white lab coat, and a hard-hat, I follow physicist Bruce Remington through the security door leading to the inner workings of the Nova laser at Lawrence Livermore National Laboratory in California, which occupies a square-mile tract of land surrounded by hills topped by windmill farms. The door opens with a magnetic card, registering on a security system the identity of the person entering.

Signs on the door read *Danger, Caution, Notice: Wear appropriate goggles*. They might as well say *Abandon all preconception of what a laser is*, for Nova is the world's largest laser, and it requires a stadium-sized building to house it.

Once inside, we enter the switchyard, a room several stories high with huge blue tubes crisscrossing the space above us. These tubes, 10 in all, are the laser beamlines. Several hundred feet away and one floor down, the beams begin their journey on a tabletop, energized by the simultaneous electrical discharge of 10,000 capacitors. Each beam travels separately in its beamline through a laser bay nearly a football field long, getting amplified and filtered to produce the final, precise laser beams. In the switchyard, the beams enter cases the size of a walk-in refrigerator that house mirrors, which point the beams at the target chamber in an adjacent room.

The target area is the sort of place for a drawn-out James Bond fight. The floors are metal grates connected by walkways and

nearly perpendicular ladders. At the center is the target chamber itself, a 15-foot-diameter aluminum sphere bolted to a metal space frame intended to protect the apparatus during an earthquake. The 10 blue tubes, each more than three feet in diameter, enter the sphere from all directions. Smaller metal cylinders for diagnostic equipment puncture the sphere. Wires festoon it and run along supporting columns. With my goggles on, the room has an orange tint.

From a porthole on the side of the target chamber I can look inside. Although the target itself—a tiny gold cylinder officially called a hohlraum but widely known as “the gold can”—is not visible, the support to which it is attached is illuminated in the center, surrounded by the pointy ends of various diagnostics and cameras. The scene reminds me of the Road Runner poised to escape a variety of missiles launched by Wile E. Coyote.

This target, however, will not escape. After technicians shoo everyone out of the target area, a two-minute countdown commences. Then the laser fires. From the control room just outside the switchyard, the event, which is called a “shot,” sounds like a large book falling to the floor. What you’re hearing is the sound of the capacitors firing.

Livermore physicist Luiz Da Silva, who has seen his share of shots, calls them “sheer excitement for a nanosecond.” He is not exaggerating: The laser pulse and its aftermath last only a few billionths of a second. Four days a week, about seven times a day, the laser fires, mostly for experiments related to the energy lab’s fusion research or its work on nuclear weapons. Scientists at Livermore are trying to fuse atomic nuclei using a method known as inertial confinement fusion (ICF). Light energy from the laser is converted in the hohlraum to X-rays. A plastic pellet filled with the hydrogen isotopes deuterium and tritium is exposed to the X-ray bath. The X-rays cause the plastic sphere to

implode, crushing the isotopes and, if the shot is successful, causing each deuterium-tritium pair to fuse into a helium atom while releasing an extra neutron—and, of course, energy.

“Nova can access parameter space that no one else can get to,” Da Silva says, which is how one physicist brags to another that “my laser is bigger than your laser.” It means that Nova can create the hottest and densest plasmas on Earth outside of a thermonuclear explosion. The temperature in the gold canister exceeds 200 electron volts, corresponding to well over two million degrees Celsius. The surface of the sun, by comparison, is a mere 6,000 degrees.

Getting astrophysicists interested in Nova took several events. One was the push begun by former Department of Energy Secretary Hazel O’Leary to declassify documents. Until a few years ago, much of the research on the Nova was classified because of its relevance to nuclear weapons. Even the dimensions and characteristics of hohlraums were secret, so some of Livermore’s own fusion scientists, including Canadian citizen Da Silva, did not know exactly what they looked like. Paralleling this diminishing secrecy, the lab is opening up to collaborations with outside scientists.

For Livermore’s Bruce Remington, who leads a group of fusion scientists studying the tendency of plasmas to behave like fluids and gases, this opening came at just the right time. Remington is an expert on Rayleigh-Taylor instability; any interface between two fluids or plasmas of different densities is prone to this sort of instability, which eventually produces spikes of the denser one poking into the less dense. A familiar example of Rayleigh-Taylor instability occurs when water is on top of oil in a jar. The fluids want to exchange places, so fingers of water force their way downward as bubbles of oil rise.

In the quest for inertial confinement fusion, scientists try to

## ***Not With a Bang but a Jolt***

Some plasma physicists claim that the structure of the universe—galaxies, clusters of galaxies, and even superclusters that form filaments and sheets over vast distances—is the result of electromagnetic forces acting on plasma. This point of view is based almost entirely on the work of the great plasma physicist Hannes Alfvén, who won a Nobel Prize in 1970 for his research in space plasma physics.

Alfvén died in 1995, but some of his former students and colleagues carry on his legacy. Their view that electromagnetism is the predominant force responsible for organizing

matter in the universe is controversial and has few adherents. According to Anthony Peratt, a plasma physicist at Los Alamos National Laboratory in New Mexico and a former student of Alfvén’s, the filamentary nature of the visible universe should have convinced most scientists that electromagnetism is responsible for its large-scale structure. Yet most astrophysicists believe the major organizing force to be gravity.

As Princeton’s James Peebles, one of the leading theorists in cosmology, puts it, “It’s clear that the dominant interaction is gravity, because the story you get for the origin of

clustering under pure gravitation makes sense.” Peebles, along with most cosmologists and astrophysicists, invokes unseen matter, called dark matter, to provide sufficient mass to cause the visible matter in the universe to cluster. Peratt and his supporters say dark matter is unproven and unnecessary.

While astrophysicists are not ready to embrace plasma models of cosmology, they increasingly realize that plasma processes are important in many astrophysical phenomena, such as the formation of accretion disks around stars or black holes, and the dynamics of pulsars and supernovae.



*The heart of the Crab Nebula glows blue with radiation emitted by electrons spiralling through its magnetic field. Such astrophysical phenomena sometimes have small-scale counterparts in the plasmas created by lasers and fusion reactors. A supernova simulation (below, right), for example, is a reverse image of the laser implosion of a fuel pellet.*

minimize Rayleigh-Taylor instability by forcing the fuel capsule to implode in a nearly smooth, spherically symmetric way that leads to the greatest compression and heating of the fuel and the most efficient thermonuclear reactions. Rayleigh-Taylor instability cannot be eliminated, however. Tiny imperfections in the interface between the two plasmas quickly grow, leading to fingers of the denser plastic shell poking into the hotter, less dense fusion fuel, quickly cooling it.

Remington, renowned among the laser scientists for his enthusiasm, single-handedly sold Nova to the astrophysics community. He is an inveterate reader of the scientific literature in fields related to his own. "I started going through the literature," he says, "and I almost came

undone when I saw a simulation of a supernova explosion." The two-dimensional simulation, showing the shock front of a supernova 256 seconds after the explosion, looks almost identical to a two-dimensional simulation of an inertial confinement fusion implosion 0.4 nanoseconds after being zapped with a laser. "My first reaction was that that can't be a coincidence," Remington recalls. "I read up on it and it's the same physics."

He began calling supernova experts, and Dave Arnett from the University of Arizona agreed to visit Livermore. He saw the football-field-size laser and was, according to Remington, underwhelmed. Remington next brought Arnett to the lobby, where a display case showed a recently declassified hohlraum, the target of all this laser energy. A microscope had been provided to help visitors see it.

Arnett, who has seen his share of particle accelerators and other big equipment, says that when he looked at the target, it

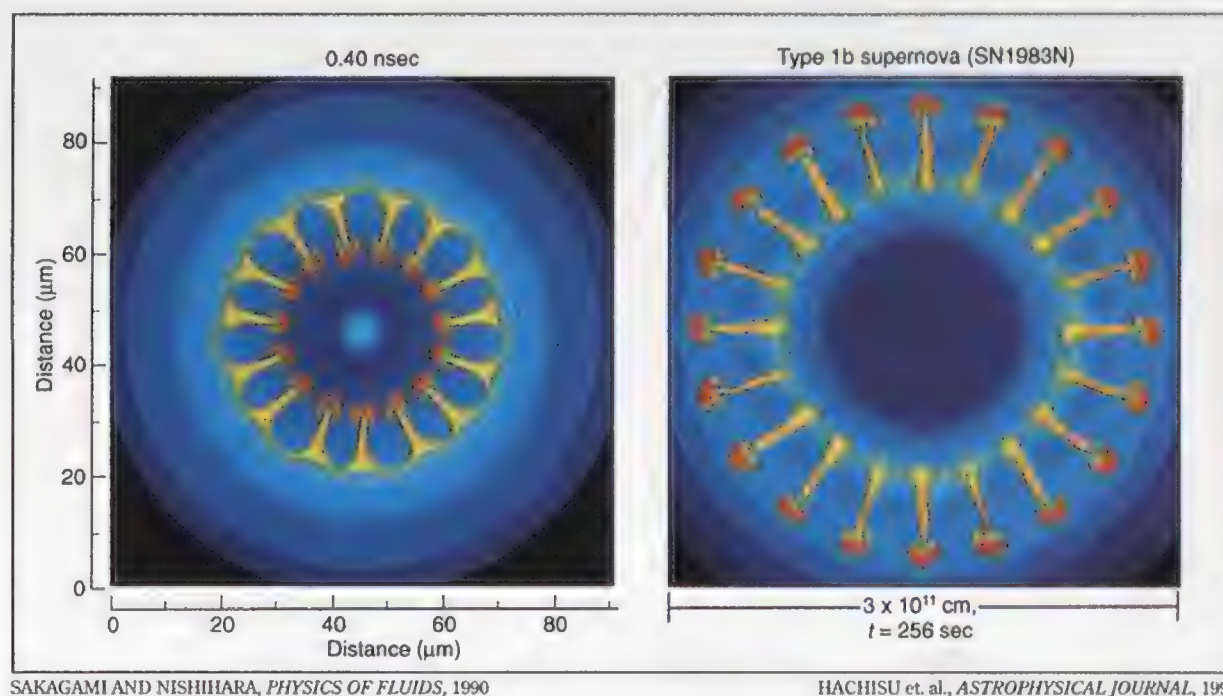
"gave me a gut feeling of how much concentrated energy we were dealing with. It was the difference between understanding these things intellectually and getting some physical intuition about them."

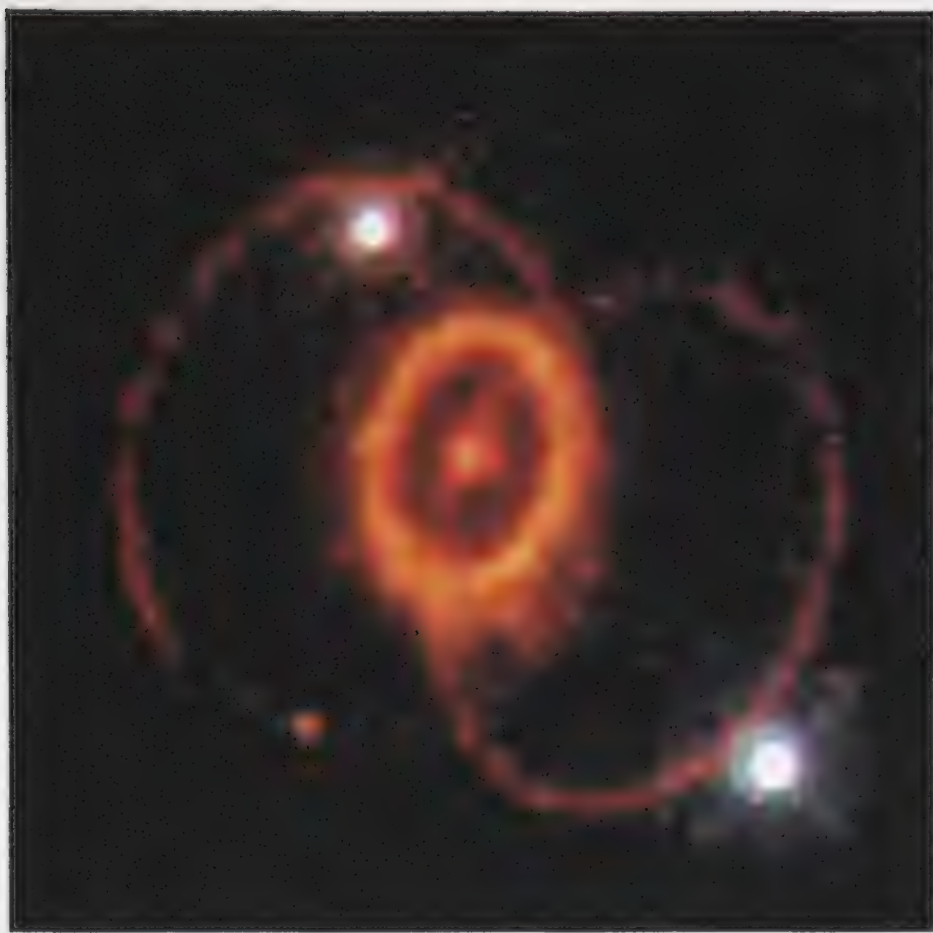
Arnett, Remington, and some colleagues began a collaboration in 1995 that continues today. To test their understanding of a physical phenomenon, physicists build models, often in the form of computer programs. The programs are then tested on their ability to simulate the phenomenon when provided realistic inputs. A great boon to supernova theorists has been the wealth of data provided by Supernova 1987A, which exploded in the southern sky on February 23, 1987 (actually, it exploded some 160,000 years earlier; that night is when its light reached Earth). SN1987A, the closest and brightest supernova to have

been seen since telescopes were invented, is a type II or core-collapse supernova, and this is how it is thought to occur: After billions of years, a star has nearly depleted its usable hydrogen fuel. The burning of that fuel by nuclear fusion had provided energy—radiation that exerted pressure outward,

balancing the star's gravity and keeping it from collapsing in on itself. The star gradually resorted to burning heavier and heavier elements until it had a heavy iron core and lighter shells surrounding it. Burning, or fusing, iron nuclei does not liberate energy, however, but consumes it. Therefore, the iron core implodes because gravity wins out over radiation pressure. When the core reaches the density of an atomic nucleus—that's very dense indeed—it rebounds, sending a shock wave outward. The shock stalls momentarily until more energy is added, then the star blows apart (see "Blast from the Past," Aug./Sep. 1988).

Computer models to simulate the fluid-like behavior of stars resemble global climate models in that they break up space into many cells, which are tracked forward in time using a set of equations. Without experimentation, Arnett says, "we could only do internal consistency checks with the theory and with data. But those checks with data weren't independent, since we were try-





SPACE TELESCOPE SCIENCE INSTITUTE

*In five to 10 years, ejecta from Supernova 1987A is expected to collide with the first of three nebular rings circling it. Scientists are using lasers to preview the dynamics of the collision.*

ing to explain the data.” The idea is to test the computer models to see if they can predict the outcomes of Nova experiments designed to simulate a supernova.

The first set of experiments was designed to better understand the role of Rayleigh-Taylor instability in accounting for data from SN1987A. Theorists had used an “onion skin” model to describe the precursor star. The outer layer, hydrogen, is the lightest, followed by helium, and then concentric spheres of increasingly heavy material until you reach an iron core. Further, supernova theories before SN1987A predicted spherically symmetric explosions, in which each layer of the star would reveal itself to observers as overlying layers expanded and thinned. Observers therefore expected to see certain elements at specific times, depending on where those elements were in the star.

Instead, there was evidence of mixing, with some dense inner layers appearing to observers far earlier than expected. At Livermore, “they know about mixing, because ICF is prone to the same sort of instability—spikes of heavy stuff, bubbles of light stuff,” says Jave Kane, a graduate student of Arnett’s who is doing his thesis at Livermore.

Arnett, Kane, and others have been revising computer models to account for the mixing. Now, says Kane, they need to test the codes to see if they are

simulating the mixing properly. In the experiments, which so far are testing the growth of Rayleigh-Taylor instability at a single boundary, the target is a layer of copper backed by a layer of less dense plastic. X-rays hit the copper, boiling off the surface layer and turning it, essentially, into a rocket engine, propelling the target forward. Meanwhile, a strong shock wave moves through the remaining copper and plastic, turning the solid to plasma. At the interface between the different-density plasmas, the Rayleigh-Taylor instability causes spikes of copper and bubbles of plastic to grow. The growth is caught on film for analysis. The scientists are using the results to refine their computer models. An experiment that lasts several nanoseconds can take 48 hours to simulate on a computer, says Kane.

Remington, with astrophysicist Paul Drake of the University of Michigan and plasma physicist Richard McCray of the University of Colorado, proposed a second set of experiments to simulate an event that theorists predict will happen in five to 10 years when the hot plasma ejected by SN1987A, having swept up slower moving plasma from the precursor star’s stellar wind, plows into denser, even slower plasma that forms a nebular ring. The experiments have just begun under the direction of experimentalist Gail Glendinning, who says confidently, “We can mock this up in the lab.”

Indeed, the day before the first of what she and her colleagues hope will be a series of more than 20 shots, Glendinning proudly showed off the target: a hohlraum 3 millimeters long by 1.5 millimeters in diameter, with an even smaller assembly attached on one side of the can to mimic the astrophysics. Her ease in handling the target belied the many days of work that went into making the parts and the day or two required to assemble them

#### NOVA LASER EXPERIMENTAL CONFIGURATION



GAIL GLENDINNING

all. In the experiment, X-rays will hit the front of a plastic disk that represents the star, creating a dense plasma that shoots off toward the back side of the assembly. This ejecta will hit and interact with a low-density foam that represents the stellar wind. Then this shocked foam and ejecta will collide with another plastic disk, representing the nebular ring.

From start to finish, the experiment will last about 14 nanoseconds. Temperatures will reach 500,000 degrees Celsius or more—high, but still much lower than in SN1987A itself. The first shot, Glendinning says, was to test how planar, or flat, the induced shock was; it has to be planar for two-dimensional computer modeling. “The worst thing we could get is blank film,” she says, referring to a camera that captures an X-ray image of the event.

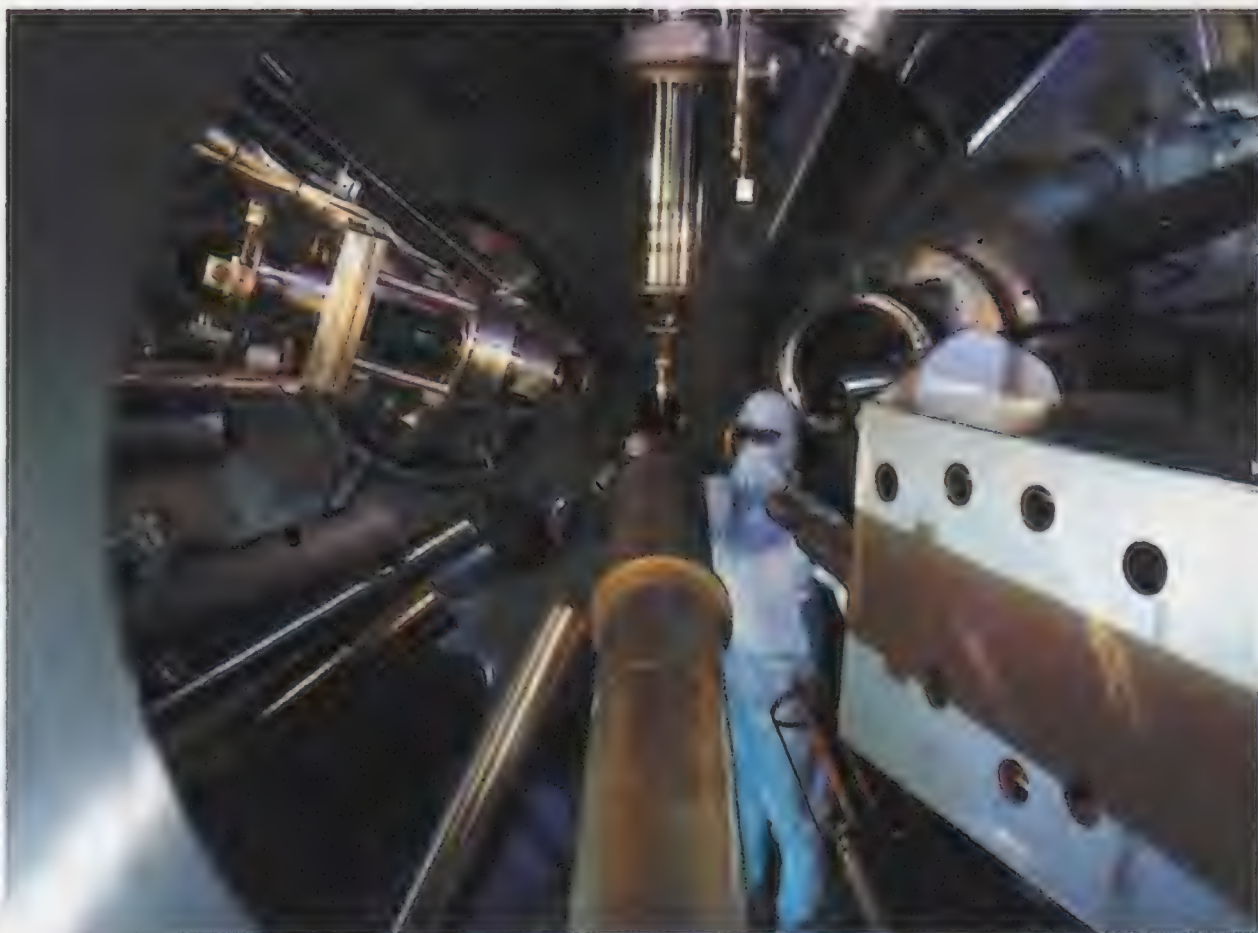
Fifteen minutes after the first shot the film came back. Blank. Glendinning and Remington soon discovered that the trigger for the camera hadn’t fired properly. After waiting a few hours to allow the laser to cool down, the physicists fired a second shot, and it worked perfectly. The shock was planar. Next up: experiments to adjust the “exposure” of the camera in order to see more of the features in the shocked material.

Some physicists aren’t so sure that the Nova experiments will lead to a new physical understanding of supernovae, but Arnett thinks they will. “We don’t know exactly how SN1987A exploded,” he says. “We are probing very extreme conditions. In order to unfold the information we have, we need to understand the explosion.” That understanding, he believes, will come from give and take between Nova experimentalists, theorists working with computer models, and observers gathering data.

But the laser experimenters deal in bursts of energy lasting only fractions of a second. What if plasma could be studied for intervals thousands of times longer?

**A**cross the country at another Department of Energy lab, on a former dairy farm in central New Jersey, scientists are exploring an alternative path to fusion energy and are also finding in some of their experiments relevance to astrophysical events. The Princeton Plasma Physics Laboratory is home to one of the world’s largest tokamaks, a doughnut-shaped bottle designed to contain a flowing plasma long enough to ignite fusion reac-

LAWRENCE LIVERMORE NATIONAL LABORATORY



*A technician cleans dust from surfaces in the Nova laser's target chamber. Inside the chamber, a hohlraum receives 10 laser beamlines (below, opposite). The target is affixed to a window at the bottom of the hohlraum to expose it to the X-ray bath inside.*

tions. The plasma, however, is extremely reluctant to be corralled and finds all sorts of ways to jump out of confinement and drop precipitously in temperature and pressure. (Because of budget cuts throughout the fusion community, the tokamak was shut down last spring. The lab continues magnetic confinement fusion research with other reactors.)

One of those ways is called magnetic reconnection—the breaking and rearranging of magnetic field lines. Just as ICF scientists try to minimize Rayleigh-Taylor mixing in their fuel pellets, those working on magnetic confinement try to prevent reconnection events that release plasma from confinement and may damage the containment vessel. Masaaki Yamada is an exception. He creates reconnection events. Yamada has been working at the Princeton lab for some 25 years doing what he calls “basic plasma physics.” He is trying to understand the fundamental plasma physics of reconnection, including its effect on plasma behavior in research reactors.

Astrophysicists are interested in his work because many believe that magnetic reconnection plays a crucial role in a number of stellar phenomena. Some believe it to be a cause of solar flares—tongues of plasma larger than Earth that burst upward from the surface of the sun. When they reach Earth, these tremendous burps of solar energy and particles disrupt satellites, communications, and electrical power and cause the brilliant dis-

plays of the auroras. Nowadays the sun is relatively quiet, with few sunspots and flares. But around the turn of the century, the end of a roughly 11-year cycle, the sun's activity will intensify.

I am at Princeton to see the recycled research reactor that Yamada has turned to the study of reconnection. First, however, he eagerly shows me some soft-X-ray videos of the sun, recorded by the Japanese satellite Yohkoh. In these wavelengths, the violent nature of the sun is clear: Constant turmoil is punctuated by occasional explosions of flame.

One of the key issues in understanding magnetic reconnection is the speed at which it takes place. According to conventional theory, the time scale for magnetic field changes in the surface of the sun is many years, says Princeton plasma astrophysicist Russell Kulsrud, a theorist who collaborates with Yamada. Yet flares are clearly occurring on a time scale of minutes. Kulsrud says that during

a flare, energy is suddenly released into empty space; theorists believe that somehow magnetic energy is being converted to thermal energy as X-rays and other particles are emitted. Measurements of the sun's magnetic field show that it weakens after a flare. It is difficult to see how you could release magnetic energy without magnetic reconnection, says Kulsrud, though he adds that it has not been proven that reconnection is the only way to do it.

Understanding reconnection events may solve another solar mystery. The surface of the sun is about 6,000 degrees Celsius. Scientists would expect its atmosphere, called the corona, to be about the same temperature. But it is far hotter, some two million degrees Celsius.

Yamada has built the Magnetic Reconnection Experiment, or MRX, in a laboratory across the hall from his office. Because of the intense interest now in reconnection, and the conviction that the physics of the MRX are directly relevant to solar phenomenon, Yamada's work is getting close scrutiny.

That makes the contrast between the MRX and Nova—which requires its own building and technical support team—even more striking. Yamada used bits and pieces of old experiments, creating an instrument that weighs several tons and requires metal I-beam supports reaching to the ground below. A reactor vessel slightly smaller than a compact car holds hydrogen gas, which is ionized by electrical discharges. Two large, circular blue coils at each end of the vessel carry electric current, creating a magnetic field to shape the hydrogen plasma and contain it. Like the

far larger Nova target chamber, the MRX chamber has numerous probes sticking out all around and metal hatches where other diagnostic instruments can be added. Among the instrumentation are magnetic probes that allow Yamada to visualize how the magnetic field changes in fractions of a second in the space of about an inch.

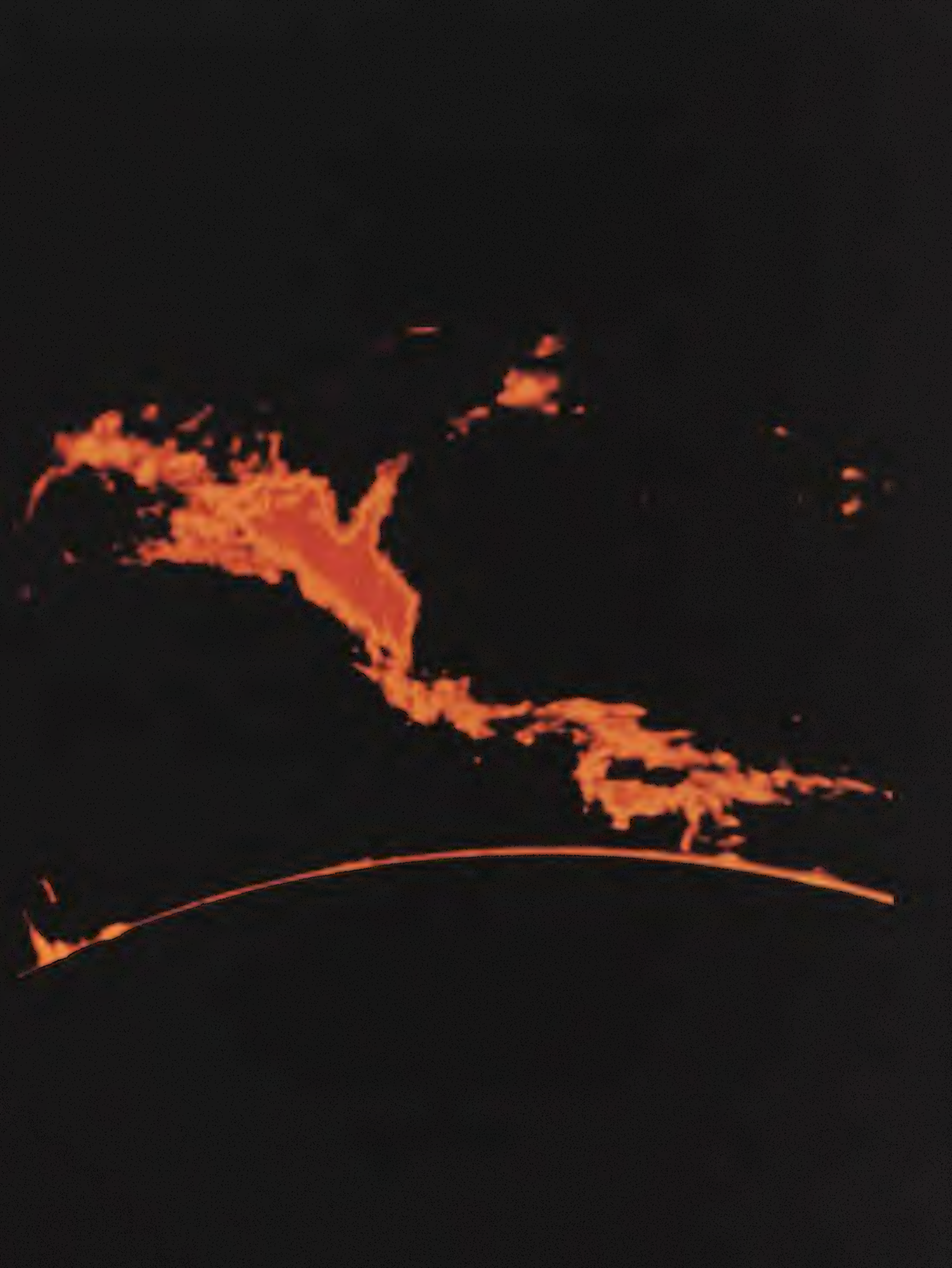
As we watch the vessel through a picture window from the hall

outside next to a flashing sign reading "Danger: experiment in progress," a capacitor bank in the room next door charges up. Electrical discharges in the hydrogen ionize the gas and create two doughnuts of plasma. Over the course of an experiment lasting several hundred millionths of a second, the magnetic field lines in those toruses will break, merge, and reconnect. Measurements of the temperatures of the plasma before and after reconnection have shown that it heats from 50,000 to 250,000 degrees Celsius. The increase in temperature supports the theory that magnetic reconnection is at least partly responsible for heating the sun's atmosphere. The lab work to extract the fundamental physics from these processes will help scientists better understand not only the sun but other stars and space plasmas, which constitute the majority of matter in the universe. ➔

*Hydrogen plasma inside a small reactor at a Princeton laboratory (above) undergoes magnetic reconnection, the same process that scientists believe triggers solar flares (opposite).*



PRINCETON PLASMA PHYSICS LABORATORY





HENRI HUET/AP

## >SIGHTINGS<

**"Requiem: By the Photographers Who Died in Vietnam and Indochina,"** a recent exhibit at the Newseum in Arlington, Virginia, presented photographs of the Vietnam war by a number of the 134 photojournalists who were killed or reported missing in Indochina, Vietnam, Cambodia, and Laos during the French- and American-Indochina conflicts. The pictures were culled from a newly published book (also entitled *Requiem*), which was a joint effort of Horst Faas and Tim Page, photographers who were wounded in Vietnam.

In "One Ride with Yankee Papa 13" by Larry Burrows (right), a helicopter gunship approaches the landing zone. Burrows squatted behind the gunner, crew chief James Farley, and triggered the shutter with a cable. The camera was mounted on a rig that swiveled with the gun, keeping the lens pointed directly at Farley.

Henri Huet photographed U.S. Army helicopters flying into a staging area (above) in "North of Saigon, Vietnam, 1966." The large rubber bladders in the foreground hold fuel for the mobile gas station.

LARRY BURROWS/LIFE MAGAZINE © TIME INC









HENRI HUET/AP

Dana Stone shows soldiers of the U.S. First Air Cavalry Division boarding a CH-47 Chinook helicopter in "A Shau Valley, Vietnam, 1968" (opposite). The CH-47 flew them out of the A Shau Valley, where they had been operating for a month against North Vietnamese troops defending the Ho Chi Minh trail.

In "War Zone C, Vietnam, 1966," Henri Huet depicts the body of a U.S. paratrooper killed in the jungle near Cambodia being lifted to an evacuation helicopter (left).

A twin-engine de Havilland C-7A Caribou plunges to earth after being accidentally hit by American artillery in "Ha Phan, Vietnam, 1967" by Hiromichi Mine (below). The ammunition-laden transport crossed a firing zone while trying to land at a special forces camp near Duc Pho on August 3. All three crewmen were killed in the crash.



HIROMICHI MINE/UPP/BETTMANN/CORBIS

# Gold and Silver Wings



ERIC LONG

**Wings and Warriors** by Donald D. Engen. Smithsonian Institution Press, 1997. 341 pp., b&w photos, \$29.95 (hardcover).

Donald Engen turned 18 on May 28, 1942—a date much anticipated by the aspiring aviator, who spent his birthday at a Navy recruiting station, parental note in hand, hoping to be accepted into a special flight training program for enlisted men. Less than two months later, Engen began ground school. Unbeknownst to him, it would be the first leg of a long and distinguished career in aviation that continues to this day.

Engen, who retired from the Navy in 1978 as a vice admiral and as deputy commander-in-chief of the U.S. Atlantic Fleet and the Atlantic Command, is currently the director of the National Air and Space Museum. As far as he has advanced professionally, however, Engen has never lost the initial enthusiasm that inspired him to become a pilot in the first place—a fact readers will appreciate, since Engen has parlayed his knowledge and passion into an intimate, insightful, and enlightening look at the evolution of the jet airplane in naval aviation “as seen

through my cockpit windscreen.”

Engen’s range is wide indeed. As he takes us along for the ride, we experience everything from combat missions and test flying to Pentagon battles and beyond. In one tense narrative of World War II action, Engen helps sink a Japanese aircraft carrier, the *Zuikaku*. In a twist of fate, 40 years after the war, Engen encounters a Japanese survivor of that attack. The former kamikaze pilot reveals that he spent five days in the water before he was rescued. The two former enemies conclude that because the *Zuikaku* was destroyed, the Japanese pilot was prevented from flying his kamikaze mission, and thus Engen had actually saved his life.

As they experienced the Navy’s transition from propeller-driven aircraft to jets, Engen and his fellow pilots explored entirely new areas of flight performance. Sometimes ingenuity was called for, such as when dealing with a loss of cabin pressure in the Grumman F9F-3 at altitudes above 35,000 feet. The answer was for pilots to simply tape their canopy rails from the inside, then remove the tape when they landed.

The book’s photos are also of great



COURTESY DON LOPEZ

interest, and vividly convey the hazards of operating aircraft from ships. In one memorable shot, a pilot sits calmly in his cockpit awaiting rescue as his A-4 Skyhawk hangs perpendicular to the water after it ran off the deck of a carrier.

Engen concludes his story with a wide-eyed look toward the future: “Knowing the past, today I marvel at what pilots and astronauts will know and do in air and space during the years to come.” Let’s all hope that someday, those same pilots will recount their exploits in books as engaging and entertaining as this one.

—Susan Katz Keating wrote “Plausible Denial” for the Apr./May 1997 issue.

**Into the Teeth of the Tiger** by Donald S. Lopez. Smithsonian Institution Press, 1997. 230 pp., b&w photos. \$17.95 (paperback).

What a pleasure it is to again read this tale, which has been updated from its original 1986 Bantam edition. Don Lopez, deputy director of the National Air and Space Museum, describes his life as a young fighter pilot (above right) in

probably the most remote U.S. theater of World War II—China.

The book begins with high action. On his ninth combat mission, Lopez is in the midst of his first air battle—12 Curtiss P-40s versus 40 Nakajima Ki-43 Oscars. He and an Oscar pilot are approaching each other head-on in firing passes. We know that the author survived; I'll not spoil the story by revealing how.

Lopez describes how in one year the Army turned an enthusiastic 19-year-old into a fighter pilot. In other hands this story, set at six bases across the South, might be less than riveting. But Lopez takes the opportunity to share his insights on the experience for the tens of thousands of young men involved, and to educate us on the massive enterprise the Army undertook to build a global air force from scratch. In Lopez's case, and I presume in the vast majority of others, the result was a thoroughly trained, skilled, and confident fighter pilot.

Lopez found himself near Karachi, India (now in Pakistan), where the new pilots received two more months of training from pilots returning from combat in China. In November 1943 he arrived in China, assigned to the 75th Fighter Squadron of the 23rd Fighter Group, which had been formed directly from the legendary Flying Tigers when they were disbanded in July 1942.

For the next year and a few months, Lopez flew more than 100 missions, as the 14th Air Force (the only U.S. fighting force in China) fought the 800,000 Japanese troops occupying much of China. Lopez participated in numerous air battles, winning the Silver Star in one for attacking and dispersing 12 Oscars after already expending his ammunition strafing ground targets. In fact, it was in bombing and strafing troops and land and river transport that the 75th Fighter Squadron was most often engaged.

With 400 hours in P-40s, Lopez had become so proficient that he flew 10 missions without altitude or airspeed information after his pitot-static system had been shot out. Initially, he and the other pilots found the first P-51s disappointing. They were faster than the P-40s, but their guns jammed if fired while pulling a few Gs.

An immensely entertaining and informative book, this update includes new material (such as an index and 25 photographs, most hitherto unpublished) but deletes two helpful features of the earlier edition. I used the simple maps in the Bantam edition to follow Lopez's battles and movements in China. The old edition also included sketches to illustrate the various airplane types Lopez encountered. These were especially helpful in identifying the Japanese aircraft.

In early 1945, Lopez, a new captain,

ended his combat tour. Typifying the casual attitude of the Army in China, an officer unceremoniously tossed Lopez his Distinguished Flying Cross and Air Medal as he was about to depart. He returned to the States 19 months after he left, a decorated veteran at 22.

—*Sam Smith is a commercially licensed pilot and an amateur aviation historian.*

**Living in Space** by G. Henry Stine. M. Evans and Co., 1997. 248 pp., \$21.95 (hardcover).

The late G. Henry Stine's last book is advertised as "a handbook for work and exploration stations beyond the earth's atmosphere" and as "a manual for survival in space." Typically, handbooks and manuals on spaceflight have information on how to go to the bathroom in a weightless environment or how to eliminate weightlessness altogether by creating some type of artificial gravity. Handbooks are to space enthusiasts what diet books are to pizza lovers—boring. They are books to have in your library in case a precocious child asks about life in space, but they're not books that one usually reads cover to cover. Why was it, then, that I found myself on the last page of *Living in Space* wanting to read more?

This book is different. Instead of beginning his book with encyclopedic facts such as the story of Sputnik or Freedom 7, Stine begins with an intellectual fact: Space is for people. The New World opened up because people were able to use it to produce something valuable for themselves and for others. Now we have an entire universe to explore. Given such a resource, there's no way people are going to turn their backs on it. Stine counters arguments that space exploration can be done better with unmanned spacecraft: "A human being can do all that a robot or machine can do and all that it can't, which is 99 percent of everything," he writes. His arguments are compelling and clear. People are in space to stay. More importantly, however, along the way we have learned something about what it means to be human.

An additional reason *Living in Space* is unique is that Stine has also placed spaceflight in a true historical context. Did you know, for example, that the idea of eating three meals a day began with King Louis XIV (1638–1715)? So many people visited his court the only way his kitchen could keep up with demands was to serve meals at regular intervals. Today, of course, spaceflights have rations for three meals a day. How much acceleration can a human tolerate? In the 1830s people believed that passengers wouldn't be able to tolerate the

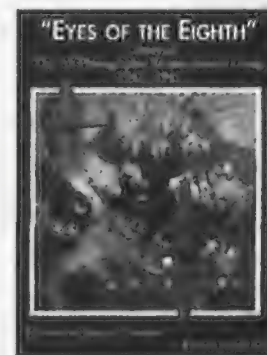
"horrendous speed of 30 miles per hour" generated by the steam-powered railway. Such stories help to remind us not only where we came from but also how far we've actually come. Although veteran astronauts might know all the technical material presented by Stine, even they will get something out of *Living in Space*.

The real appeal of the book is that it is as much philosophy as science. Stine uniquely describes what it is to be a human being and to live in a time when it's possible to travel to space—his book is about both living and space. Sure, you're going to learn things like how to have sex in zero-G, but you will also learn something more. As Stine explains, "the late historians Will and Ariel Durant wrote in the introduction to their monumental series, *The Story of Civilization*, 'Let us, before we die, gather up our heritage, and offer it to our children.'"

These words are hauntingly prophetic. With this publication so near his recent death, G. Henry Stine did precisely that.

—*National Air and Space Museum planetary geologist Bob Craddock's career was launched when he purchased an MPC Nike Smoke kit at age 12, one of many model rockets designed by G. Henry Stine.*

**Eyes of the Eighth: A Story of the 7th Photographic Reconnaissance Group, 1942–1945** by Patricia Fussell Keen. CAVU Publishers, 1996 378 pp., b&w photos, \$35.00, (hardcover).



Spying is often referred to as the second oldest profession. In war, the gathering of intelligence regarding the capabilities and intentions of the enemy is often the difference between victory and defeat. With the advent of air warfare, a new type of intelligence was required, also necessitating new methods of collection and analysis. Although it was always important to know the disposition of the enemy's armies—where they were located, in what strength, and where they were headed—air warfare required something far different. Because an enemy's entire economy was vulnerable to air attack, detailed intelligence on the economy—the location of the major steel mills and arms factories, the railroad network, and the electric power grid—was now essential. In addition, once a target was attacked, it was necessary to determine the extent of damage so that further air strikes could be scheduled if required. The primary method of obtaining this type of intelligence became

the job of reconnaissance aircraft armed with cameras, not guns.

*Eyes of the Eighth* is the story of the 7th Photographic Reconnaissance Group, part of the Eighth Air Force, which was stationed at Mount Farm, Oxfordshire, during the Second World War. Patricia Fussell Keen is well acquainted with the Eighth Air Force, having assisted Roger Freeman in his classic works on that subject. Keen takes on the less glamorous though no less important task of chronicling the story of the recon pilots who took off, "unarmed and unafraid," to photograph German occupied territory. Usually unescorted, the group's pilots flew F-5s (modified P-38 Lightnings) and Spitfires stripped of their armament so they could fly higher and faster—they hoped—than the Luftwaffe fighters and anti-aircraft guns trying to stop them. As a result, the recon planes relied on speed and guile to perform their mission. That was not always enough; the group lost over 60 men and another two dozen became prisoners of war. This was an unusually high price for a unit of this size.

The book contains dozens of outstanding photographs that help explain the importance of the 7th Group's mission. Some of the most amazing photos are those of German rocket sites, source of the terror weapons directed at London and other urban centers in England. A top priority of Allied bombers, these V-1 and V-2 sites were small and heavily camouflaged. The recon photos thus often had to be taken at treetop level and below. Even then, it required the expert mastery of the photo interpreters to note tell-tale signs of launch ramps and hidden transporter vehicles. The problem was not unlike that encountered by Allied Coalition recon pilots and photo interpreters attempting to eradicate the Iraqi Scud menace during the Persian Gulf war of 1991. Similarly, it was the combined efforts of the aircrew—usually officers—and the ground crew and interpreters—largely enlisted—that brought success. The author strikes an effective balance between covering the activities of both these groups.

Keen also tells a very human story of men in combat far from home and family simply trying to do their duty. One also is particularly struck by the youth of the men—almost everyone in the 7th Group was in their early 20s. The pictures of those lost in combat, forever young, remind us of the heavy price always exacted by war. In addition, Keen's descriptions of combat missions, too often ending in death or shoot-down, are outstanding. She is adept at relating

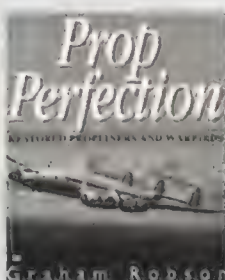
incidents that many pilots shared; especially memorable are the vignettes of those who became prisoners of war or who succeeded in evading enemy capture.

Overall, this is an excellent account of an often overlooked mission that was absolutely essential to Allied success in World War II. Because the author focuses on the activities of a single reconnaissance group, a reader must have an understanding of the air war in general and the Eighth Air Force in particular to fully appreciate Keen's effort.

—*Air Force Colonel Phillip S. Meilinger is a professor at the U.S. Naval War College in Davisville, Rhode Island. He wrote "The Next Air Campaign" for the Oct./Nov. 1997 issue.*

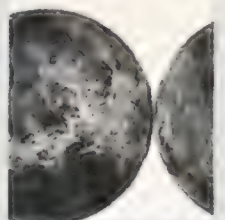
### Book Briefs

**Prop Perfection: Restored Propliners and Warbirds** by Graham Robson. *Classic Motorbooks*, 1997. 112 pp., color photos, \$24.95 (paperback).



Glossy photos of rejuvenated B-17s, A-26s, Connies, and other less celebrated aircraft like Fairchild C-123s and Grumman S-2s.

**Atlas of Venus** by Peter Cattermole and Patrick Moore. *Cambridge University Press*, 1997. 143 pp., color and b&w photos and illustrations, \$29.95 (hardcover).



Colorful images and maps of topographic features of the cloud-shrouded planet plus an index of every Venusian feature and an explanation of its name.

**The Spirit of Naval Aviation** by M. Hill Goodspeed. *Naval Aviation Museum Foundation*, 1997. 148 pp., color and b&w photos, \$35.00 (hardcover).



Tour the National Museum of Naval Aviation in Pensacola, Florida. Color photography by *Air & Space* contributing editor Chad Slattery.

**Getting There Is Half the Fun.** Former astronaut Norman E. Thagard is a professor of electrical engineering at Florida State University. Of all the air- and spacecraft he has flown, his favorite is the McDonnell F-4 Phantom jet, which he flew in the U.S. Marine Corps.

**Seven Days at Dryden.** Peter Garrison has been working on a homebuilt airplane of his own design for 16 years. He expects to finish it before he dies.

Further reading: *Flights of Discovery: 50 Years at the NASA Dryden Flight Research Center*, Lane E. Wallace, NASA, 1996.

**Gone but Not Remembered.** Bruce McCall is a writer and illustrator whose work frequently appears in the *New Yorker*. His memoir of growing up Canadian, *Thin Ice*, was published last year by Random House.

**Bigfoot.** John Sotham is an associate editor of *Air & Space/Smithsonian*. He once gave himself a black eye reattaching the left main gear doors of an A-10 Thunderbolt II.

Further reading: *Aircraft Landing Gear Design: Principles and Practices*, ed. by J.S. Przemieniecki, American Institute of Aeronautics and Astronautics, 1988.

*The Lore of Flight*, Chancellor Press, 1986.

**Bomberville.** Frequent contributor Lance Thompson believes there's no better job than traveling through the United States to write about aviation. (Thompson is also the author of this issue's Collections.)

When on assignment, Michael Melford can generally be found lugging half a dozen cases of heavy photographic equipment. So he was especially happy to work on this story: It took place practically around the corner from his home, and he photographed all of the images with a lightweight Polaroid camera and a single lens. But with only one camera around his neck, he worried that no one would take him seriously.

**Rockets for the Rest of Us.** Charles Petit is a reporter for the *San Francisco Chronicle* and writes frequently on astronomy and space technology.

Photographer Phil Schofield says it was refreshing to work with a group of people who, when asked about the technological challenges they face, can honestly say, "It is rocket science."

**Igor Sikorsky's Little Bird.** Although he could visit Moscow only by phone,

writer John Fleischman had the privilege of seeing Igor Sikorsky's private office at the Sikorsky Helicopter plant in Stratford, Connecticut. "They dust but otherwise it's kept exactly as Mr. Sikorsky left it the day before he died in 1972," says Fleischman.

Further reading: *Sikorsky S-16*, Vadim Mikheyev, Flying Machines Press, (phone 203-378-9344), 1997.

**Star in a Bottle.** Billy Goodman is a writer who specializes in science. His feature "The Planet Hunters" (Oct./Nov. 1992) won an award from the American Institute of Physics.

## CALENDAR

### February 15 & March 15

Open Cockpit Sunday. Approximately 12 aircraft will be open to visitors. New England Air Museum, Bradley International Airport, Windsor Locks, CT, (860) 623-3305.

### February 21 & 22

EAA Chapter One Open House and Fly-In. Flabob Airport, Riverside, CA, (909) 686-1318.

### February 24-March 1

Asian Aerospace '98. Singapore Changi Exhibition Centre, phone 65-434-3677.

### March 6-8

Cox Communications Air Show Spectacular. Williams Gateway Airport, Mesa, AZ. Tickets available through TicketMaster.

### March 7 & 8

Rocky Mountain Air Fair. Wings Over the Rockies Aviation and Space Museum, Denver, CO, (303) 776-7481.

### March 12-14

Women in Aviation Conference. Adam's Mark Hotel, Denver, CO. For more information, write to Women in Aviation, Intl., Morningstar Airport, 3647 S.R. 503 South, West Alexandria, OH 45381.

### April 16-19

Reunion: 396th Bomb Squadron of the 7th Air Force's 41st Bomb Group. San Antonio Holiday Inn Northwest, TX, (409) 694-9584.

*Organizations wishing to have events published in Calendar should submit them four months in advance to Calendar, Air & Space/Smithsonian, 901 D St. SW, 10th Floor, Washington DC 20024. Events will be listed as space allows.*

• Telescopes • Binoculars • Biology • Optics • Photography Accessories •

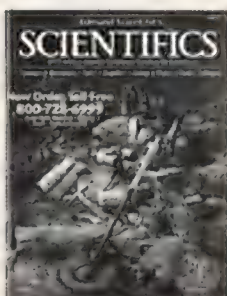
Educational Science Toys • Geology • Telescopes • Binoculars • Biology • Optics

Educational Science Toys • Geology • Telescopes • Binoculars • Biology • Optics

Do you think of this  
as the Big Dipper?



Astroscan® 2001, pg 3  
\$329.00



Or, an unfortunate obstruction  
to viewing the M-51 galaxy?

The big picture comes into focus when viewed through the Astroscan® 2001. Its unique design and convenient table-top base make it extremely ideal for beginners and serious astronomers alike. Plus, its amazing 3° field and superb light gathering capability make those panoramic views all the more memorable. Call 800-728-6999 for a free catalog.

**Edmund Scientific**  
If you love science.

SCIENTIFICS CATALOG DIVISION

Dept. A981C901, 101 E. Gloucester Pike, Barrington, New Jersey 08007-1380  
E-mail us at: [scientifics@edsci.com](mailto:scientifics@edsci.com)

• Telescopes • Binoculars • Biology • Optics • Photography Accessories •

# THE AVIATION SERIES

**DEATH RATTLERS**  
From basic training to combat.  
Color/55 minutes/V-14483

**FLYING TIGERS**  
Americans with modern aircraft and military "know-how".  
B/W & Color  
65 minutes/V-6987

**B-24's AT WAR IN THE PACIFIC**  
Series III takes you on the "Road to Japan".  
B/W & Color/52 minutes/V-5885

**Additional Selections...**  
F4U Corsair • The B-24 Story • C-47's at War • Battle of Britain • P-38 & P-40 • The P-51 Story

**A PERFECT GIFT FOR THE HOLIDAYS!**

**ONLY \$19.95 EACH** plus S&H

To place an order or receive a **FREE** complete catalog of "The Aviation Series" call American Sound & Video at **1-800-869-6379**

Dept. 64  
**AMERICAN SOUND & VIDEO CORPORATION**

## HANDCRAFTED AVIATION DISPLAY MODELS

Over 500 Aviation Display Models Available

ALBATROS D-V "GORING"  
(1/20th = W/S: 17.75")  
@ \$169.95 + \$9.00 S/H

### SHOWCASE MODEL CO.

P.O. Box 129, Dept. A/S-98-02  
Covington, OH 45318-0129 U.S.A.  
(800) 441-9524 - Orders ONLY  
(937) 473-5725 - Catalogs/Questions  
(937) 473-5727 - FAXES



WORLD'S LARGEST MAKER OF AEROSPACE REPLICAS



## ALL NEW 60-PAGE COLOR CATALOG



Order our aviation art catalog for \$7.50, and we will include a certificate good for a 20% savings on your first order. The Stokes Collection, Box 1420, Pebble Beach, CA 93953

**1-800-359-4644**

## KITES

### FREE COLOR CATALOG

Choose from over 200 exciting kites.  
• Many unusual & innovative designs.  
Call or write for your catalog today!

Into The Wind • (800) 541-0314  
1408-K Pearl St., Boulder, CO 80302

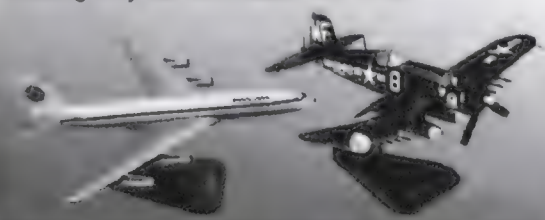


## AIRLINER NUT? World's Largest

selection of airline and airliner related items: books, videos, models, calendars, shirts, posters, pins, magazines, etc., including our own **AIRLINERS**, The World's Airline Magazine. Call (800) 875-6711 or (305) 477-7163, fax (305) 599-1995 or write: AIRLINERS Catalog, PO Box 521238/AS, Miami, FL 33152-1238 USA for a free fully-illustrated catalog.

## AVIATION MODELS

The Airplane Shop has the largest selection of commercial & military aviation models & collectibles! Fully assembled, meticulously detailed, complete with stand. Color catalog only \$2. refundable with order.



### THE AIRPLANE SHOP

18 PASSAIC AVENUE, UNIT 6, FAIRFIELD, NJ 07004  
TEL: 1-800-PLANE-GO • FAX 973-244-1227

## ON THE WEB SITE



CAROLYN RUSSO

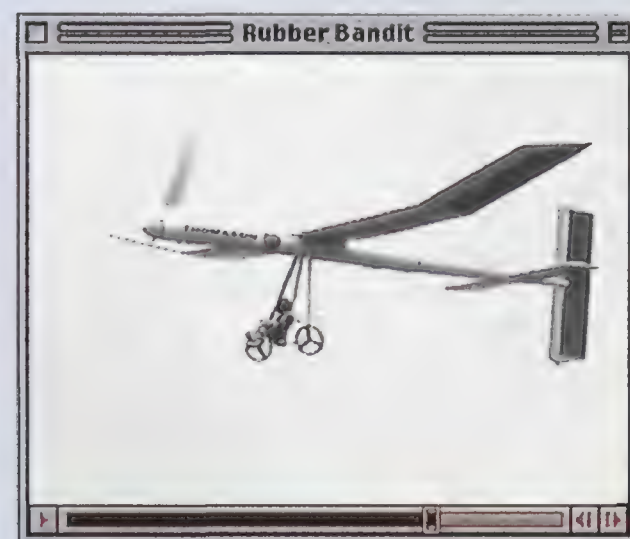
# Meet Susan Still

Susan Still piloted the space shuttle *Columbia* on a 16-day mission last summer. In a recent interview, she talks with the editors about making it through test pilot school, flying F-14 Tomcats, getting picked to be an astronaut, and taking that long trip in space.

([www.airspacemag.com/TWD/still.html](http://www.airspacemag.com/TWD/still.html))

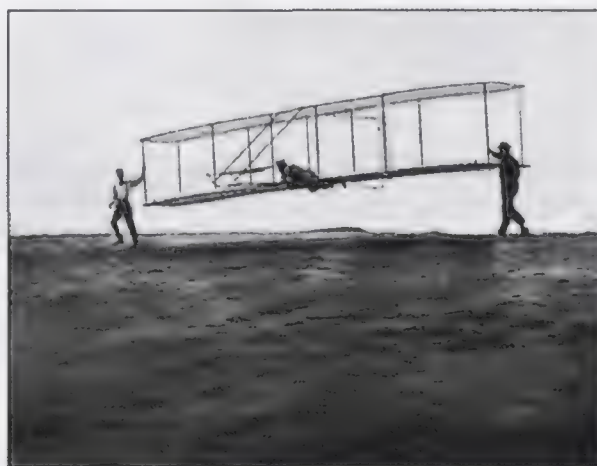
## Bandit et al.

A scale model of the world's first piloted, rubber-band-powered airplane takes a test hop at *Air & Space/Smithsonian's* Web site. Also on view: the X-13 Vertijet, the Martin Mars water bomber, and the Northrop YB-49 Flying Wing. Hardcore sports fans can catch historic footage of the 1992 "Malice in Dallas" arm wrestling match between Southwest Airlines honcho Herb Kelleher and Stevens Aviation CEO Kurt Herwald. ([www.airspacemag.com/ASM/Web/Site/sightings.html](http://www.airspacemag.com/ASM/Web/Site/sightings.html)).



## FORECAST

## In the Wings...



NASM

### Re-Wrighting History

In 1902 a graceful construction of ash, pine, and muslin taught the Wright brothers the secrets of controlled flight. Today a Virginia craftsman has re-created the fragile glider to teach the rest of us.

### The MOL Men

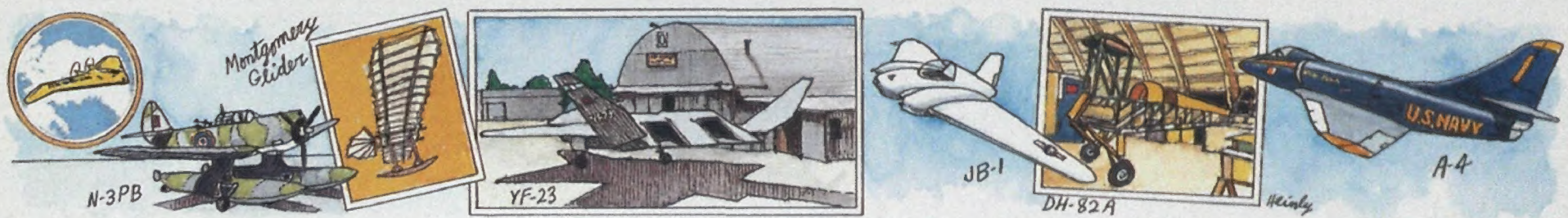
Before the Pentagon canceled the Manned Orbiting Laboratory, the Air Force had 17 of its best pilots training for 30-day missions in space. Seven joined NASA as astronauts. What happened to the remaining 10?

### One Mean Helicopter

One of Russia's fiercest aircraft, the Mi-24D Hind attack helicopter, showed up one day in Fort Bliss, Texas, and Army gunship pilot Jeff Stayton got new orders: See what that baby can do.

### Will the Chipmunk Survive?

The last of the tail-draggers is being retired from Her Majesty's Service, but pilots the world over are proving you can't keep a good Chipmunk down.



JOHN HEINLY

# Westward Ho!

**W**here are the bombs? Where are the bullets?" Those are the questions most school-age visitors ask Fred Erb when they first enter the Western Museum of Flight. Erb, the museum's director, doesn't mind the fixation on firepower as long as it gets the kids through the door. Once they're inside, he can use the museum's eclectic array of memorabilia, unusual aircraft, and modern warplanes to teach them something about the history of aviation.

The Western Museum of Flight is located across the runway from the Hawthorne, California factory where Northrop built the famous Flying Wing bombers. Under the museum's Quonset hut roof is a collection of artifacts that spans over a century of flight. There's a full-scale replica of the first American hang glider, in which John Montgomery soared from a San Diego mesa in 1883, as well as wind tunnel models of fighters designed for combat beyond 2000. Sharing the tight space are five ongoing restorations that provide visitors a nuts-and-bolts view of how aircraft are constructed.

Restoration gave the museum its start. In 1981, a group of volunteers from Northrop came together to restore a N-3PB floatplane. N-3PBs were Northrop's first production aircraft, and the company built only 24. This particular specimen had crashed in Iceland in 1943; the restorers started with essentially nothing but twisted metal and had to manufacture many replacement parts. When they were done, the group donated the craft to Norway's Oslo Aviation Museum.

The restoration team became the nucleus of the Western Museum of Flight, and volunteers there continue to restore vintage aircraft. The museum is currently working on several World War II artifacts. There's a Link trainer simulator, which looks like a coin-operated kiddie ride, a fabric-covered de Havilland DH-82A Tiger Moth trainer, and a North American XAT-6E powered by a Ranger 12-cylinder in-line engine instead of the usual Wasp

radial. Sharing the workshop space are a 1946 Stinson 108 and a Vietnam-era Lockheed YO-3A powered glider that was used for reconnaissance.

The YO-3A has been the 10-year project of museum volunteer Bill Johnson, who got his first aviation job in 1943, working on B-25s and P-51s for 85 cents an hour. The YO-3A he is restoring was one of 12 built by the Lockheed Missiles & Space Company for the Army. The YO-3A, says Johnson, was "the original stealth aircraft," modified to fly almost silently. It had a three-blade propeller, which was

---

*The Western Museum of Flight, 12016 Prairie Ave., Hawthorne, CA 90250. Phone: 310-332-6228; Web site: [www.wmof.com](http://www.wmof.com). Open Tues.-Sat., 10 a.m.-3 p.m. Admission: adults \$3, kids \$2.*

---

quieter than the factory-installed six-blade prop, an exhaust system with multiple mufflers, and a sound-deadening rubberized coating on the engine's rocker arm covers. Says Johnson: "It was so quiet, flying overhead at 100 feet at night, it sounded like leaves rustling in the breeze." Johnson has been aided in his restoration by a YO-3A crew chief he found through the Internet.

Supervising the care of the museum's lineup of modern jet fighters is Jim "JJ" Johnson, a volunteer whose 20-year career with Northrop included a round-the-world tour as crew chief on an F-20 Tigershark fighter prototype. The jets in the collection range from some of the most widely used combat aircraft in the world to a few rare species. An A-4 Skyhawk sports the blue and gold of the Blue Angels. The museum's F-5A still wears the livery of its Norwegian air force donors (they sent the Northrop-manufactured fighter to thank the Northrop team for the N-3PB floatplane). An F-14A on display was restored with parts from many sources, including a Tomcat slated for the gunnery range at Fallon Naval Air Station in Nevada.

Rare aircraft on the ramp include an unusual example of Northrop's famous flying wings—the JB-1. Designed as America's answer to the V-1 buzz bomb that the Germans fielded in World War II, the wing was never used in combat because a suitable engine couldn't be found. The puffy-looking JB-1 on display has a cockpit for a test pilot, but production models would have been remote-controlled, and each would have been armed with two one-ton bombs.

The museum's YF-17, one of only two made, narrowly lost an Air Force fly-off to the YF-16 in 1975. But Northrop's YF-17 prototype evolved into the phenomenally successful F/A-18, which was developed as a joint effort by Northrop and McDonnell Douglas. Another rare Northrop prototype dominates the jet fighter collection—the extremely stealthy YF-23, designed for sustained supersonic flight without use of an afterburner, one of two designs that competed to be the first new Air Force fighter of the next millennium. (The Lockheed Martin F-22 Raptor won the distinction.)

The museum is also amassing extensive media archives. Unusual films in the 16-mm collection include a briefing the Dutch air force conducted on operations in the East Indies in 1939 and a Russian report on Yuri Gagarin's 1961 orbit of Earth in Vostok 1. Treasures in the technical library range from original blueprints for Howard Hughes' Spruce Goose to 4,500 pounds of F-14A tech orders.

Seeing schoolchildren wander through the museum, touching the cylinder heads of a Wright Cyclone radial engine or peering into the inlet ducts of the YF-23, reminds Bill Johnson of his own childhood. "My dad used to take me to airports when I was a little kid to watch the planes," he says. "I did the same with my son, he did the same with his son. You pass that love of airplanes from generation to generation. When I was a kid, I would have loved to come to a place like this."

—Lance Thompson

# USSR



BE-4



I-16



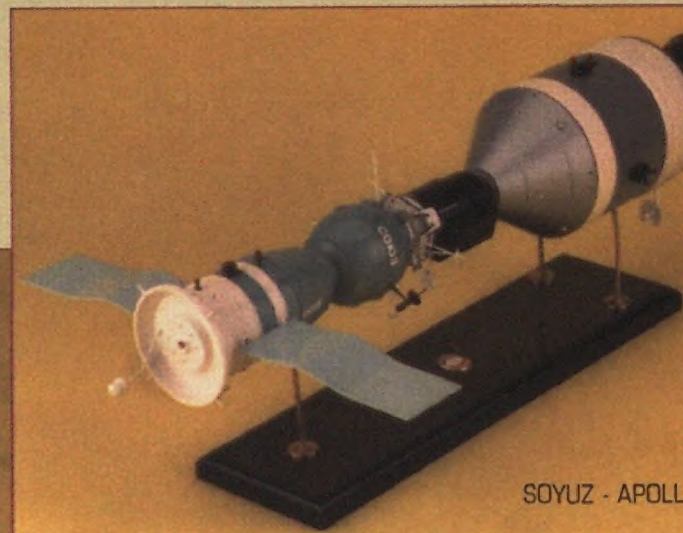
FIRST SPUTNIK



MiG-3



TU-22



SOYUZ - APOLLO



A-40



TU-160



LA-5



SU-9



SU-26



MiG-29



YAK-28



SU-100 / T-4



IL-2



SU-27



MiL-10



YAK-3



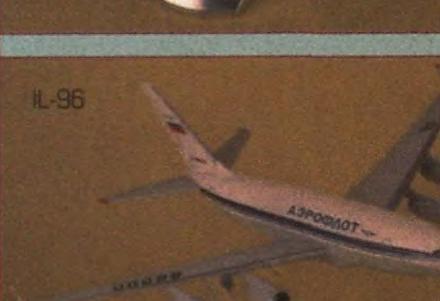
TU-104



MiG-15



AN-225



IL-96



# Collectables



1 ROCKET

ROTON  
CKET

VOSTOK



VVA-14



S.KOROLEV,  
Y.GAGARIN,  
STATUE OF  
COSMONAUT

In 1903

Konstantin

Eduardovich

Tsiolkovskiy published his book, "Space Exploration By Means of Reaction Propulsion Craft," in which he expounded the scientific foundations of space rocketry.

This event marked the first scientific theory of spaceflight ever published. It also served to mark the beginning of more than 90 years of Soviet/Russian breakthroughs in space exploration.

In addition to their many "firsts" over the years, the Russians have the world's only space station, more launch vehicles, including the world's most powerful rocket engine, (and their own space shuttle), than any other country; many other space engines/vehicles and spacecraft not available in any other space programs; and, of course, the only "Real (Long-Term) experience" living and working in space.

The greatest testimony to their grand achievements in space is reflected in the fact that all the other spacefaring nations are involved in cooperative space projects with Russia.

Following are a few of the many accomplishments in USSR Space History:

- FIRST ARTIFICIAL SATELLITE OF EARTH: "SPUTNIK" WAS LAUNCHED ON OCTOBER 4, 1957, WHEN THE SPACE EXPLORATION ERA STARTED.
- FIRST SPACE TRAVELER: THE FIRST LAUNCHING OF A LIVING BEING INTO SPACE OCCURED ABOARD SPUTNIK-2 WITH A DOG NAMED LAIKA

- FIRST MAN IN SPACE: YURI GAGARIN MADE HIS HISTORIC FLIGHT ON APRIL 12, 1961.
- FIRST TO ORBIT THE SUN
- FIRST TO THE PLANETS
- FIRST TO THE MOON
- FIRST TO VENUS
- FIRST TO MARS
- FIRST ARTIFICIAL SATELLITE OF THE MOON
- FIRST PHOTOS OF THE FAR SIDE OF THE MOON
- FIRST LANDING ON THE MOON
- FIRST SOIL FROM THE MOON
- FIRST CAR/ROVER ON THE MOON
- FIRST ARTIFICIAL SATELLITE OF VENUS
- FIRST LANDING ON VENUS
- FIRST LANDING ON MARS
- FIRST SPACE SHIPS AND SPACE STATIONS
- FIRST WOMAN IN SPACE
- FIRST MULTI-MAN CREW IN SPACE
- FIRST SPACE "WALK" BY A MAN
- FIRST SPACE "WALK" BY A WOMAN
- FIRST AUTOMATIC DOCKING OF MANNED AND UNMANNED SPACECRAFT
- FIRST RETURN TO EARTH AFTER CIRCUMLUNAR FLIGHT
- FIRST CREW TRANSFER IN SPACE
- FIRST SIMULTANEOUS FLIGHT OF THREE SPACE SHIPS
- FIRST DOCKING OF A SPACESHIP TO A SPACE STATION
- FIRST UNMANNED FLIGHT OF A SPACE SHUTTLE
- FIRST MANNED SPACE STATION
- LONGEST SPACE FLIGHT - MORE THAN A YEAR
- LAUNCHED JANUARY 8, 1994 COSMONAUT POLYAKOV SPENT OVER 14 MONTHS ABOARD "MIR"
- IN FEBRUARY, 1994 COSMONAUT KRIKALEV FLEW ON THE AMERICAN SPACE SHUTTLE
- IN 1995 AMERICAN FLEW TO "MIR" ON A RUSSIAN "SOYUZ"

- SPACE SHIP AND AN AMERICAN SPACE SHUTTLE DOCKED WITH RUSSIAN SPACE STATION "MIR"
- IN 1975 DOCKING OF SOYUZ-19 WITH APOLLO STARTED A NEW ERA OF SPACE COOPERATION

All these and other great accomplishments in unique pieces of memorabilia selected from Cosmonauts, Space Program Officials, Russian Space Museums, Private Collectors in Russia.

One of a kind collectibles presented in presentation desk top display models, produced exclusively by original design bureaus for display at airshows, museums and presentation to business partners.

History of Russian Aviation (1875-1997) and Space (1957-1997) in Pins, Wings, Desk Top Medals, Award Medals, Patches, Stamps, Covers, Post Cards, Posters, Photos, Books, Magazines, Art, Uniforms, Flight Suits, Helmets, Equipment, Autographs, Souvenirs, Aeroflot collectibles.

Over 200 Aircraft & Space Models in Catalogue (SASE; 2-stamps, U.S.; 3-coupons, international).

For other memorabilia info please call first Phone (818) 999-1134

Fax (818) 592-0033

Telephone inquires will be taken first

Alex Panchenko

P.O. Box 5069

West Hills, CA 91308 USA

*"Earth is the cradle of all mankind - but man cannot live in the cradle forever." - Tsiolkovskiy*



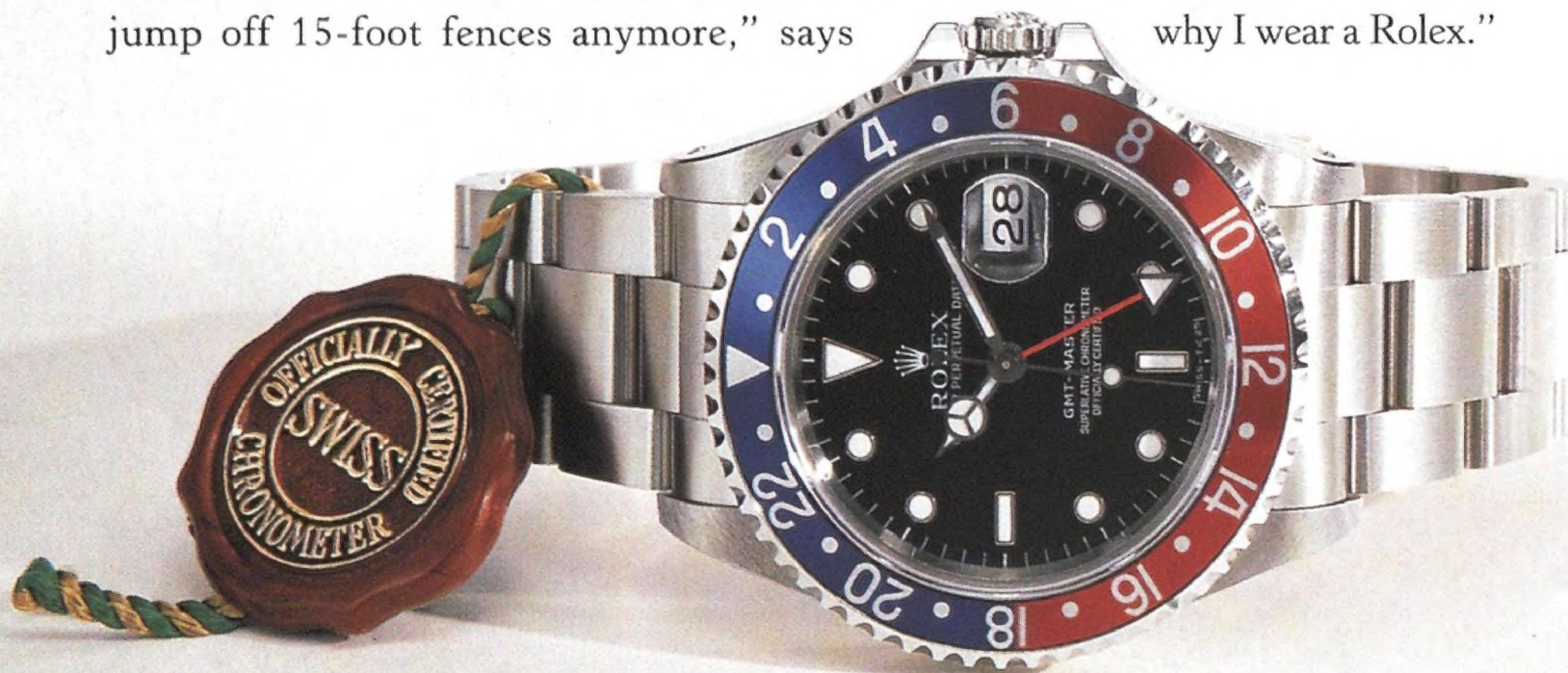
**"If you want to grow old as a pilot, you've got to know when to push it, and when to back off."** *Chuck Yeager*


At 21, only three years after first boarding a plane, Chuck Yeager was leading a squadron of fighter pilots in World War II. And at the age of 24, he became the first person to fly faster than the speed of sound.

Yeager remains a man very much on the move. He's an avid sportsman and a consulting test pilot who still loves to fly. "Maybe I don't jump off 15-foot fences anymore," says

Yeager, "but I can still pull 8 or 9 G's in a high-performance aircraft." And in all his exploits, Chuck Yeager depends on a rugged and reliable timepiece. "I wore a Rolex back in 1947 when I broke the sound barrier and I still wear a Rolex today," says Yeager matter-of-factly. "A pilot has to believe in his equipment. That's why I wear a Rolex."

  
**ROLEX**



Rolex Oyster Perpetual GMT-Master Chronometer in stainless steel with matching Oysterlock bracelet.  
For the name and location of an Official Rolex Jeweler near you, please call 1-800-36ROLEX.  
Rolex, , Oyster Perpetual, GMT-Master and Oysterlock are trademarks.